

## AIRSHIPS RETURN!

Rediscover the most elegant way to fly



## DOOMSDAY VOLCANO

The biggest threat to civilisation lies right under our feet



## A QUESTION OF GRAVITY

Are we about to solve science's biggest mystery?



AUSTRALIAN

# SCIENCE ILLUSTRATED

MEANWHILE  
ON EARTH...



## IN THE DEEP

2000M DOWN, THINGS  
GET PRETTY WEIRD



## SUPERSONIC SUBMARINES!

THE ULTIMATE WEAPON  
FOR FUTURE WAR?

# Life?

COULD EUROPA'S HIDDEN OCEAN  
BE HOME TO AN **ALIEN ECOSYSTEM**?

**+** *Plus!*

- 3** AUDACIOUS  
MISSION PLANS  
DETAILED
- 3** OTHER WORLDS  
WHERE LIFE  
COULD THRIVE



## ELEVEN WORDS THAT SPARKED A REVOLUTION

“Wait a minute, wait a minute,  
you ain’t heard nothin’ yet.”

Al Jolson’s first spoken words in *The Jazz Singer* mark the first appearance of synchronized dialogue in a feature-length motion picture. Art mirrored life. Moviegoers truly hadn’t heard anything like this before. And when they did, they wanted to hear more. *The Jazz Singer* had less than two minutes of spoken dialogue. But it sparked a revolution nonetheless.



*The Jazz Singer, 1927*

### SOUND CHANGES EVERYTHING

Pictures are pictures. Pictures with sound are transformational. That’s why *The Jazz Singer* hit Hollywood like a seismic wave. In its wake, silent films have all but disappeared.

---

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# SCIENCE ILLUSTRATED

Issue #36 (23rd April 2015)

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Science Illustrated is published  
7 times a year by nextmedia Pty Ltd  
ACN: 128 805 970  
Building A, 207 Pacific Highway  
St Leonards, NSW 2065

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## THE SCIENCE ILLUSTRATED CREDO

We share with our readers a fascination  
with science, technology, nature, culture  
and archaeology, and believe that through  
education about our past, present and future,  
we can make the world a better place.

# The greatest threat is one we can do nothing about



**R**emember that old made-up-by-the-English "Chinese" curse: May you live in interesting times? We sure live in interesting times, and while we may be on the road to our own

destruction, even if we mend our ways, our survival is anything but guaranteed.

Earth's tectonic activity - the way the crust "floats" on a deeper layer of viscous rock - encourages the proliferation and evolution of life. As the continents shift and merge, animals migrate and interbreed. Continental drift and the way it changes everything from basic geography to the climate itself, directly created *Homo sapiens*. We are who we are because we responded to geographical change, and so evolved and became more intelligent.

But tectonic activity is also enormously destructive. Our most powerful nuclear weapons can produce a bare percentage of the energy released by an earthquake. The USSR's Tsar Bomba unleashed 50 megatons of destruction, but the Boxing Day Tsunami's output was measured in the *gigatons*.

It's humbling to think that no matter how cleverly we deploy our technology curtail the release of harmful chemicals into the air and reverse the effects of global warming, all this could be wiped out in an afternoon by a megaquake or a supervolcano.

Average-sized eruptions like Tambora in 1815 and Krakatoa in 1883 disrupted human civilisation. And earlier eruptions like Santorini in the Mediterranean, Lake Taupo in New Zealand and Baekdu in China were big enough to destroy entire cultures.

But all these pale into insignificance against the truly big eruptions. Eruptions like the Toba catastrophe which occurred around 70,000 years ago, and nearly drove us to extinction. The signs of that eruption remain in our DNA, where scientists can clearly identify a "genetic bottleneck" which shows we may have been reduced to as few as 15,000 individuals.

Toba ejected thousands of cubic kilometres of ash and rock into the atmosphere and pumped out gigatons of sulfur dioxide. It was worse for the climate than all the human industry of the last century. It changed the world, and changed us.

Yet these events, when set against a geological timescale, are common. The Earth's history is punctuated by countless thousands of massive eruptions, each one shaping the land and changing the life that lives upon it.

For us, the Yellowstone caldera could one day mark a very definite full stop in the story of our civilisation. There's a little we can do to prevent its eruption. If Yellowstone does go off, that's pretty much the immediate end of the USA, and the perhaps inevitable end of human agriculture. It's a sobering thought.

Of course the biosphere itself will bounce back - it always does. And we've survived such events, as a species, before. Just. For most of us, the thought of a supervolcano or a massive tectonic event is so huge, there's very little point in worrying about it.

It could be worse. We could live on Venus. There, the entire crust melts every few hundred million years. Planets be crazy.

**Anthony Fordham**

Twitter: @sci\_illustrated

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## THINGS WE LEARNED IN THIS ISSUE

- + Deep in the ocean **GIANT VERSIONS OF ORDINARY BUGS** feed on dead whales.
- + We could one day sail a **ROBOT SUBMARINE** through a secret underground ocean on Europa
- + By giving children **THREE PARENTS** doctors can defeat most genetic diseases.
- + When you fly **BY AIRSHIP** it's all about serene comfort and enjoying the view.





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Spiders. Sometimes scary. Sometimes like a tasty summertime dessert.

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## ↓ SWORDS CROSS IN A FRENETIC AERIAL JOUST

Measuring 110 mm, the beak of the sword-billed hummingbird is longer than the bird itself, and the longest of any hummingbird species. The beak can reach nectar from long, tube-shaped flowers, but the bird can also use its extremely long equipment for defensive purposes. A sword-billed hummingbird in search of the best nectar has ventured into the territory of a collared inca. The inca gets aggressive, but the sword-billed bird easily puts its rival to flight.

JAN VAN DER GREEF









MEGAPIXEL

NEUROLOGY





## ↓ GET LOST ON THE LONG AND WINDING ROADS OF YOUR BRAIN

Brain cells communicate via complex, widely connected networks, but the exact way in which the cells interact remains a mystery. Now, scientists have invented a mathematical model which can translate electrical impulses in a brain into an image of an intricate neural network, using a supercomputer. The densely packed neurons and their links are coloured so they are easier to make out. Knowledge of the brain's complex routes of communication may lead to new ways of treating diseases such as epilepsy or even Alzheimer's.



Editors: Karen Grubbe

**23** cats have had their genomes sequenced with the aim of studying the genetic development of domestic cats.

# ANTARCTIC SEA ICE PROVES THICKER THAN EXPECTED

The ice surrounding Antarctica is up to 17m thick.

**GEOLOGY** A yellow robotic sub has been on a mission under the sea ice off Antarctica, bringing back surprising news: The ice is considerably thicker than expected.

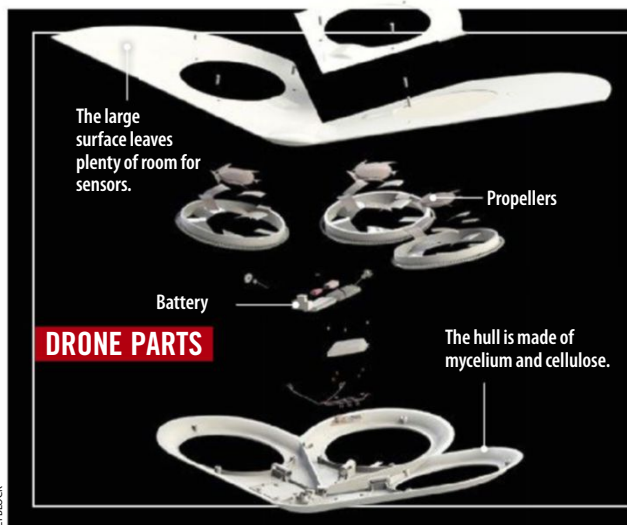
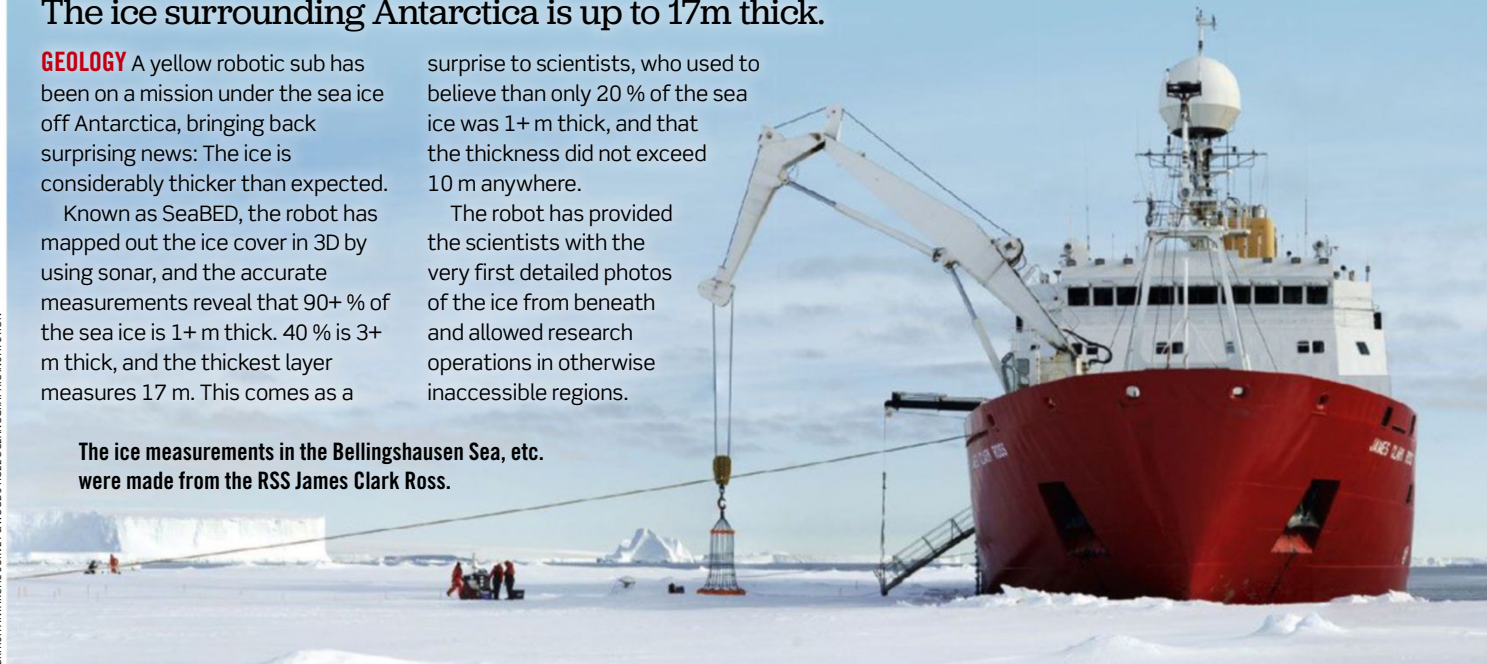
Known as SeaBED, the robot has mapped out the ice cover in 3D by using sonar, and the accurate measurements reveal that 90+ % of the sea ice is 1+ m thick. 40 % is 3+ m thick, and the thickest layer measures 17 m. This comes as a

surprise to scientists, who used to believe that only 20 % of the sea ice was 1+ m thick, and that the thickness did not exceed 10 m anywhere.

The robot has provided the scientists with the very first detailed photos of the ice from beneath and allowed research operations in otherwise inaccessible regions.

The ice measurements in the Bellingshausen Sea, etc. were made from the RSS James Clark Ross.

BRITISH ANTARCTIC SURVEY & WOODS HOLE OCEANOGRAPHIC INSTITUTION



## DRONE PARTS

## DRONE BUILDS AND DESTROYS ITSELF

**TECHNOLOGY** Drones are everywhere and now also come in a biodegradable version. In popular terms, the drone can build itself, and if lost, it will self-destruct, turning into harmless sugar.

The inventors of the ground-breaking vehicle are students from different US universities. The hull is made of cellulose and mycelium, which are tiny, fibrous fungus cells.

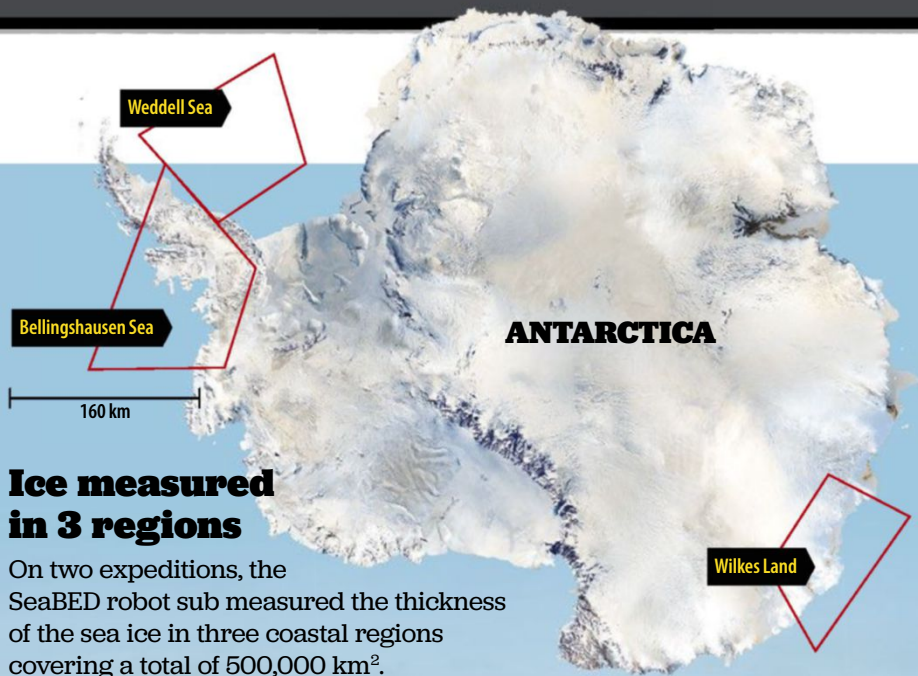
The materials used make the drone easy to carry along to places such as Mars, as the astronauts will only need to bring a few spores, which can subsequently form the basis of the bio-drone.

## COMPLETE DRONE



ELI BLOCK





## Ice measured in 3 regions

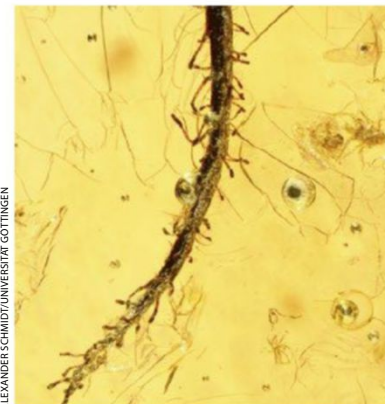
On two expeditions, the SeaBED robot sub measured the thickness of the sea ice in three coastal regions covering a total of 500,000 km<sup>2</sup>.



The robot is 2 m long, weighs 200 kilograms, and can dive 30 m.



The robot is remote-controlled by means of navigation equipment.



ALEXANDER SCHMIDT/UNIVERSITÄT GÖTTINGEN

Scientists have found the first fossil of a carnivorous plant.

## CARNIVOROUS PLANT FOUND IN AMBER

**PALAEONTOLOGY** In an amber mine near the Russian city of Kaliningrad, scientists from the German University of Göttingen have discovered the world's oldest example of a carnivorous plant in amber.

The specimen is 35-47 million years old and consists of two leaves with long "hairs", which were sticky and functioned as efficient flypaper.

This is the first ever amber sample of a carnivorous plant. So far, scientists have only found seeds and pollen from the hungry plants.

## ► NEWS FLASH!

### MANY BABIES = EARLY DEATH

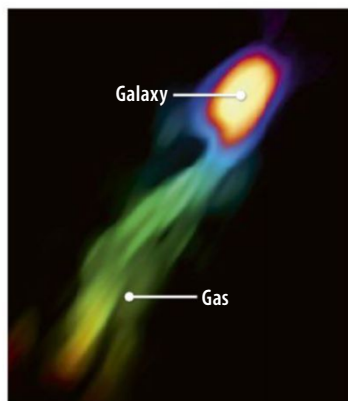
Large broods drive bird parents to an early grave. In an experiment, a team of scientists moved the offspring of 186 jackdaw parents, so some got more babies and others fewer. 59% of the birds with large broods were alive the next year, but 72% of the birds with small broods survived.

## ONE FRENCH KISS, 80 MILLION BACTERIA

When we exchange French kisses, some 80 million bacteria pass from one person to the other, according to a Dutch study, in which scientists registered the bacterial flora in the saliva of 21 couples before and after a 10 second French kiss. The bacteria "trade" is not necessarily a bad thing, as the bacteria - depending on the species - may protect the receiver against different diseases.

SHUTTERSTOCK





Galaxies release gas when new stars form inside them.

## ASTRONOMERS SPOT EXTREME GALACTIC GAS

**ASTRONOMY** Astronomers have for the first time observed a galaxy, hurling huge amounts of cold, dense gas from its interior.

The phenomenon is the universe's equivalent of vapour emitted from a pressure cooker, and it occurs when new stars form at a high rate inside the galaxy. The new stars are so hot and shine so brightly that the gas surrounding them is swept out of the galaxy and moves tens of thousands of light years away – in this case at a speed of 1,000 km/s.

Known as SDSS J0905+57, the galaxy was observed “burping” by an international team of scientists headed by UK astronomer James Geach.

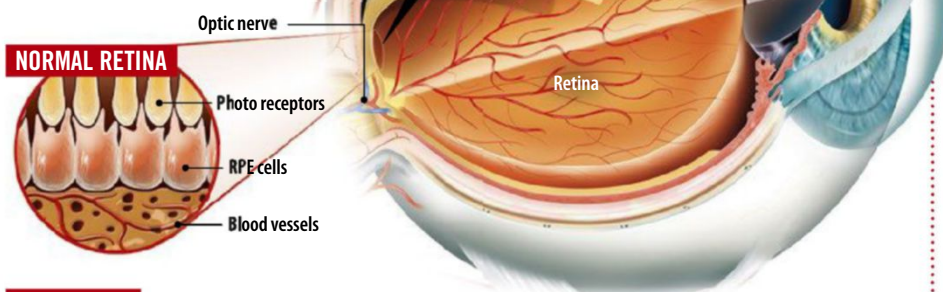
### ► NEWS FLASH!

## GOOGLE CARS SMELL GAS

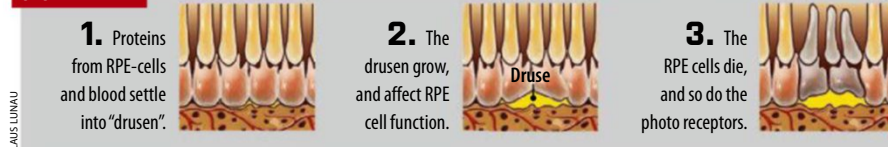
Those Street View cars do more than take photos. Thanks to a suite of sensors, the cars, that are otherwise busy mapping out cities, have found hundreds of gas leaks in Boston, New York and others.

## Retina cells revived

Eye diseases such as AMD are caused by retina nerve cells breaking down and dying off.



### SICK RETINA



# STEM CELLS MAKE BLIND PEOPLE SEE AGAIN

New cells have replaced sick ones in 10 patients.

**MEDICINE** A woman who could not see any of the letters of the eye specialist's test chart, can now easily read the top four rows. It sounds like a miracle, but the woman and 17 other patients have been given experimental stem cell therapy, trying to cure two incurable eye diseases.

In more than 50 % of the cases, the result was amazing: Suddenly, they could read and write, recognise faces, see colours, and go shopping again.

The test subjects suffered from AMD - age-related macular degeneration or from Stargardt disease, which

is a hereditary eye disease. Both may cause considerable visual impairment or at worst blindness. In the experiment, scientists from the US Advanced Cell Technology company in Massachusetts injected stem cells into the retina of the eye, where the new cells replaced damaged cells.

One year after the stem cell therapy, 10 patients had actually improved their eyesight while the other participants' vision had at least been stabilized. Exciting for doctors, the treatment seems to have absolutely no side effects.



Scientists insert stem cells into one of the 18 test subjects.



# STRANGE

— BUT TRUE!

## ► Paint turns sunlight into energy

Mercedes-Benz has introduced a new, energy-friendly car, the Sports Utility Coupé, with paint that generates energy. The paint functions as a solar cell, generating an electrostatic charge, when the wind hits the surface of the car.



## ► Captive-bred animals reject wild partners

Wild and tame don't mix. That is the conclusion of a new research project, in which geneticists observed the mating patterns of mice in the wild and in captivity. A group of mice lived in a cage for three generations and were subsequently introduced to wild mice. Only 17% of the mating happened between members of the two different groups.

## ► Humans obey robots

We obey the boss — also when he is a robot. In an experiment, a team of test subjects were asked to name files for 80 minutes, while the work was monitored by a small, human-like robot. Although the participants tried to stop working several times and argue with their robotic boss, 46% of the participants completed the task.

10

ivory combs and an image of a bearded man were discovered recently by archaeologists in a 5,600-year-old Egyptian tomb.



## LOCAL FOCAL POINT

Antarctica



## Rover prevents stress among penguins

Penguins get stressed out and feel uneasy if humans come too close. But they take it easy, if they get in close contact with a remote-controlled car disguised as a young penguin, according to an experiment carried out by French scientists in an Antarctic penguin colony.

YVONLE MAHO

## EGYPTIAN BOOK FULL OF MAGIC

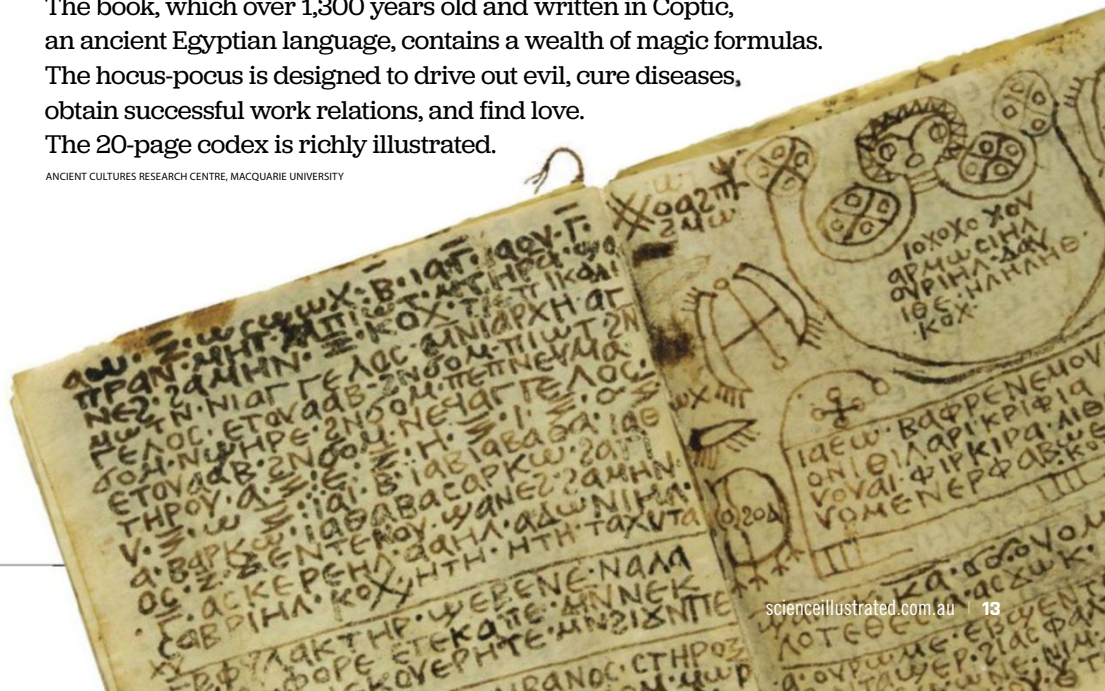
Australian scientists have decoded an Egyptian handbook of magic.

The book, which over 1,300 years old and written in Coptic, an ancient Egyptian language, contains a wealth of magic formulas.

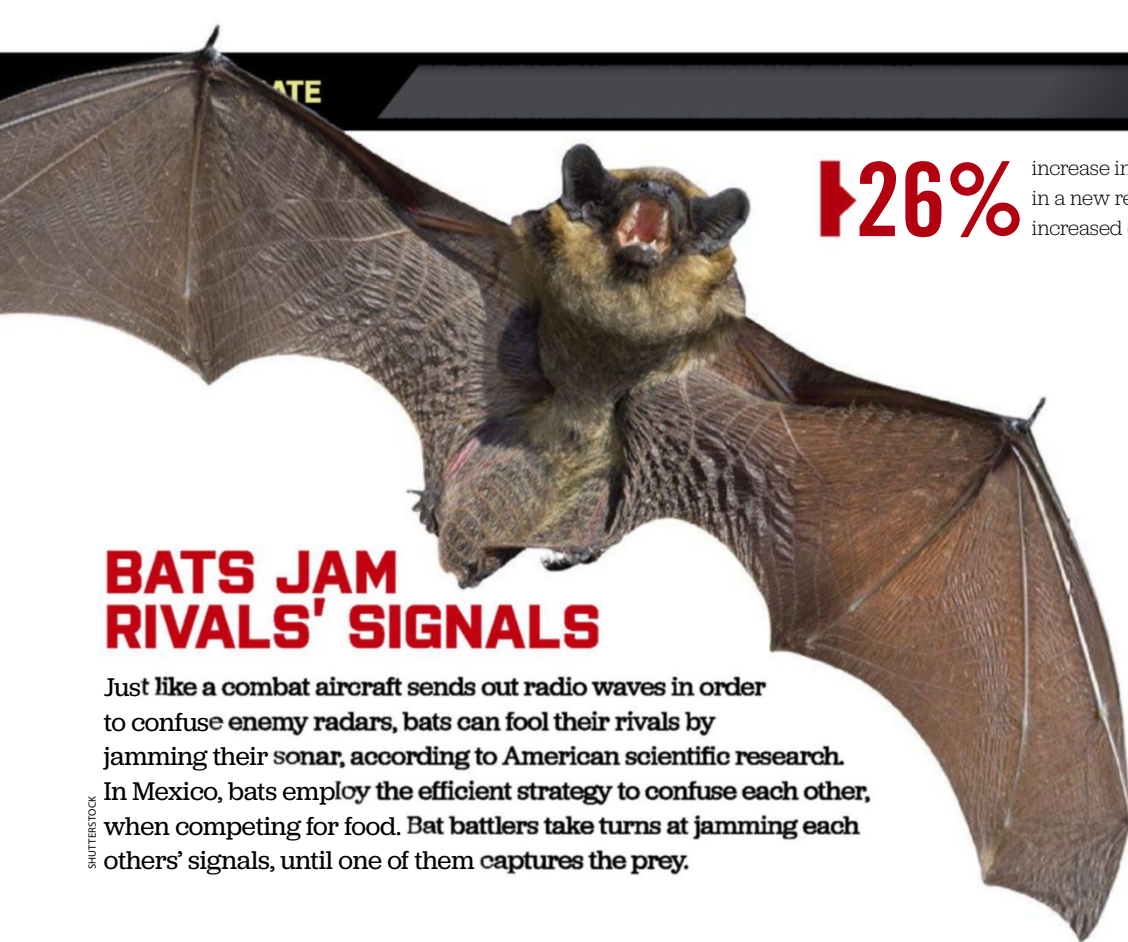
The hocus-pocus is designed to drive out evil, cure diseases, obtain successful work relations, and find love.

The 20-page codex is richly illustrated.

ANCIENT CULTURES RESEARCH CENTRE, MACQUARIE UNIVERSITY







26%

increase in ocean acidity. That's the figure in a new report, which links the rise to increased carbon dioxide in the air.

## BATS JAM RIVALS' SIGNALS

Just like a combat aircraft sends out radio waves in order to confuse enemy radars, bats can fool their rivals by jamming their sonar, according to American scientific research. In Mexico, bats employ the efficient strategy to confuse each other, when competing for food. Bat battlers take turns at jamming each others' signals, until one of them captures the prey.

SHUTTERSTOCK

### ► NEWS FLASH!

## MENTHOL BOOSTS ADDICTION

People who smoke menthol cigarettes smoke more and find it harder to quit, according to a new study. Intensified cravings are caused by the way menthol increases the number of nicotine receptors in the brain.



CHINESE CULTURAL RELICS

The familiar site of a cat playing with a ball, 1000 years ago in China

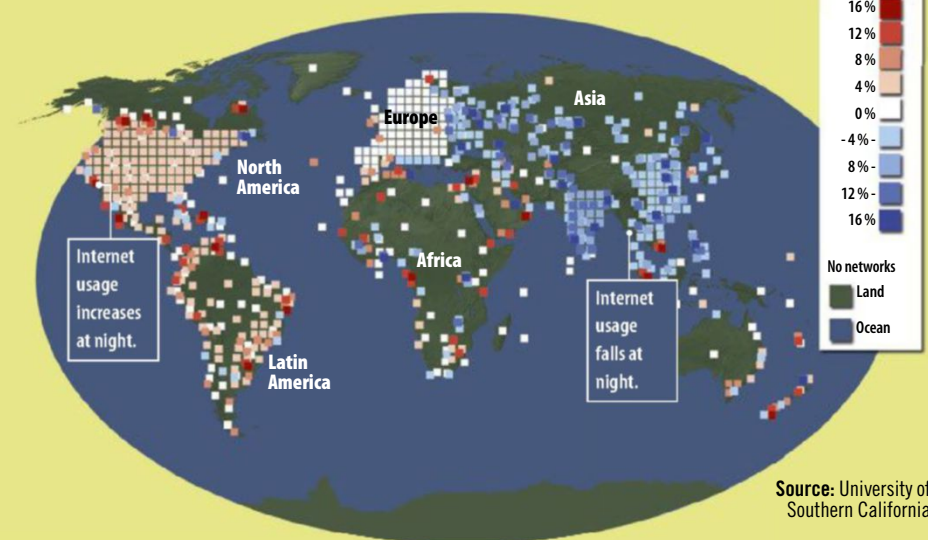
## MURALS DEPICT DAILY LIFE IN CHINA

**ARCHAEOLOGY** We do not know who rests in 1,000-year-old tomb which discovered by archaeologists in Northern China. But the deceased was probably an important person, because his tomb is decorated with beautiful expensive murals.

The murals vividly and colourfully depict scenes from the occupant's daily life, including servants bringing food and drink. The tomb does not hold any bones, but features a 1-m-tall statue of a smiling man, who is probably the "owner".

### THE INTERNET NEVER SLEEPS

In North America and Europe, the Internet never sleeps, but in Asia and Africa, the usage drops at night.



## THE INTERNET SLEEPS IN MAJOR PARTS OF THE WORLD

**TECHNOLOGY** In Western Europe and the US, people use computers and the Internet 24/7, but in other parts of the world, the activity depends on the time of day, according to

data collected by Californian scientists. In Asia, Eastern Europe, and South America, people are active online throughout the day, but they sign off in the evening.

CLAUS LUNAU





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# WHAT WILL YOU BE DOING THIS NATIONAL SCIENCE WEEK?



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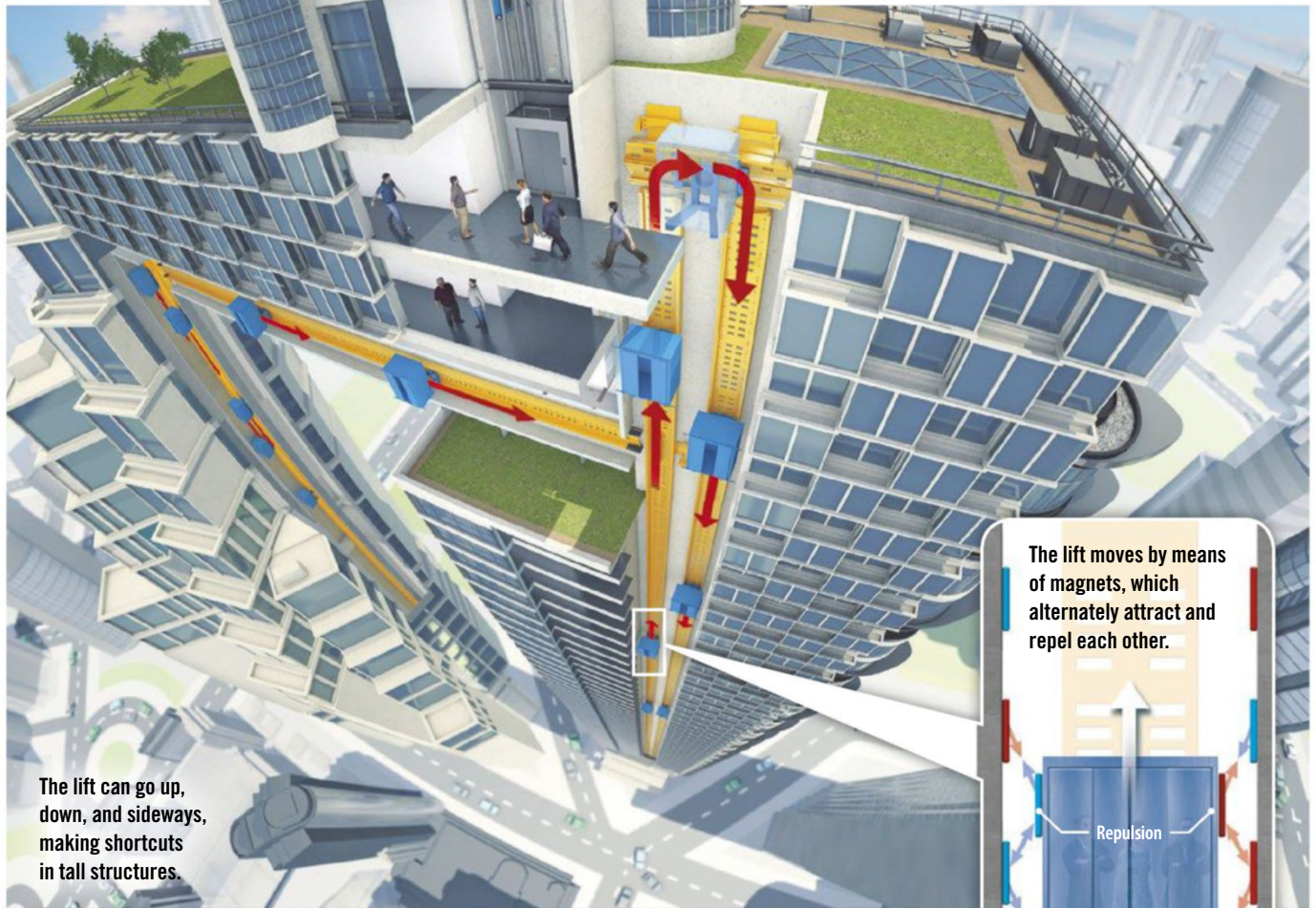
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The lift can go up, down, and sideways, making shortcuts in tall structures.

# MAGLEV LIFT GOES UP, DOWN, AND SIDEWAYS

The lift of the future travels in a magnetic field.

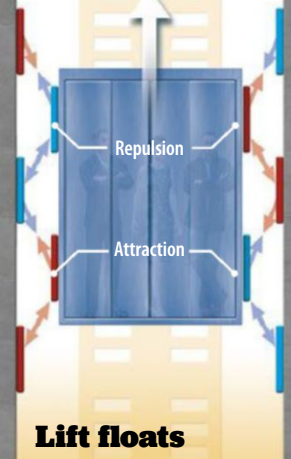
**TECHNOLOGY** Like other lifts, the lift of the future can of course go up and down. But that's not all: The lift can also go sideways. What's more, it has no cables, but floats in a magnetic field just like a maglev train.

German industrial megacorp ThyssenKrupp is responsible for the breakthrough lift, which so far only exists as a 3D model. But according to plan, a prototype of the lift will

be tested in a 240m-high tower in the German city of Rottweil in late 2016, and it will be put into service as quickly as possible.

As the lift does not include any cables, the shaft may hold multiple lift cabins, moving in loops. According to ThyssenKrupp, the maglev lifts will be able to carry 50% more people, while reducing wait times to between 15 and 30 seconds.

The lift moves by means of magnets, which alternately attract and repel each other.



## Lift floats on magnets

The lift cabin is powered by an electric motor and keeps floating in the shaft due to magnets repelling each other. The technology is known from maglev trains, which are powered by means of electromagnets.



# The Foundation for the Advancement of Astronomy supporting excellence



The Foundation for the Advancement of Astronomy, established by the Astronomical Society of Australia, recognises excellence through the Society's activities.

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# Why do landslides often occur along rivers?

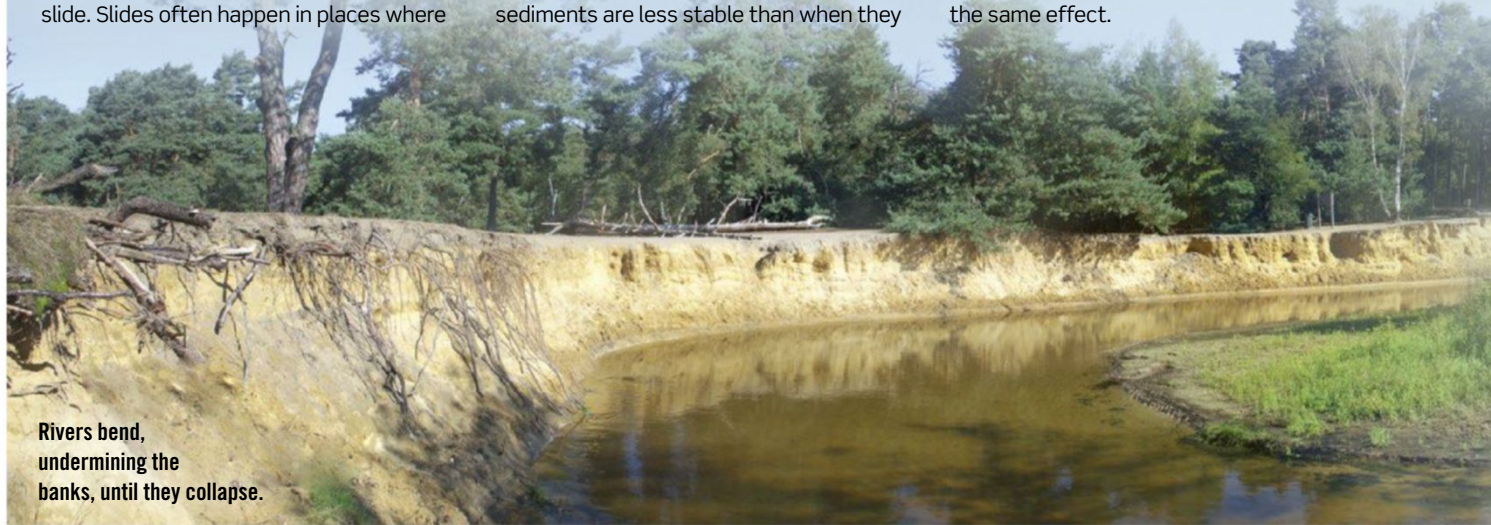
**Do landslides occur more often along rivers, and do some types of subsurface slide more easily than others?**

Slides along rivers occur because the river bed is constantly in motion. The river acts almost like a liquid bulldozer, undermining the bank to the point, in which they slide. Slides often happen in places where

the river flows through a landscape of sediments such as soil, sand, and gravel, which is much easier to erode than hard rock, so rivers passing through such sediments are very lively, making large bends, known as meanders, through the landscape.

Slides often occur in connection with drought or heavy, continuous rain, as sediments are less stable than when they

are only slightly moist. If sand is either bone-dry or soaking wet, it is harder for the individual grains to hold on to each other, and the slightest motion may cause a slide. Think about sandcastles at the beach: If the sand holds too much water, the castle immediately crashes, whereas sand that has been dried too long by the Sun causes the same effect.



Rivers bend, undermining the banks, until they collapse.

SHUTTERSTOCK, GETTY IMAGES © CLAUS LUNAU

## WHY DOES A MOBILE PHONE GET HOT?

The more a mobile phone works, the warmer it gets. Inside the phone, all the electric components must be powered by moving electrons. However, the electrons cannot move freely. They collide with impurities and other electrons as they go, generating heat, like when you rub your hands against each other. If Wi-Fi, Bluetooth, and GPS are activated at the same time, more power is on the move, producing more collisions and more heat.



SHUTTERSTOCK

### IN SHORT

#### DO WOMEN GET MORE URINARY TRACT INFECTIONS?

Women suffer cystitis more often than men. Due to the “design” of human female genitalia, women have a shorter urethra, so intestinal bacteria can more easily find their way to the bladder, causing infection.



## FATAL SLIDE CLAIMED 43 LIVES

The winter of 2013-2014 was unusually warm and rainy in Washington State, USA. Rain had softened the steep banks of the Stillaguamish River. The river itself was well up, gaining power to erode the banks. On 22 March 2014, 15 million tonnes of sand, clay, and gravel set in motion from a plateau 200 m above the river. The water-saturated sediments turned into a mud tsunami measuring several metres and flooded the village of Steelhead Haven.

A large part of the plateau buried a village on the riverbank.



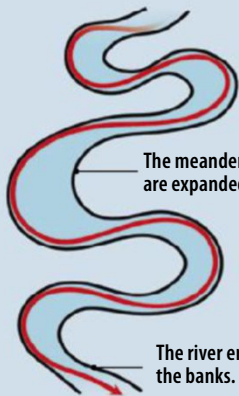
## A RIVER ERODES ITS BANKS



1. Water flows downwards, following the route of least resistance which is never a straight one. Over time, it bends ever more.

The water speed is higher at the outer curves.

Bends known as meanders occur.



The meanders are expanded.

The river erodes the banks.

2. The water flows faster at the outer curves, known as meanders. The faster the water flow, the more erosion. Consequently, the river expands the meanders, eroding the banks more and more, until they finally slide.

The individual legs of the giant huntsman measure more than 15 cm!

## TOP 5

### WHICH IS THE BIGGEST SPIDER?

#### 1. Giant huntsman

(Heteropoda maxima)

Leg span: Up to 30 cm

Habitat: Caves in Laos

#### 2. Goliath birdeater

(Theraphosa blondi)

Leg span: Up to 28 cm

Habitat: Northern South America

#### 3. Brazilian giant tawny red tarantula

(Grammostola mollicoma)

Leg span: Up to 26 cm

Habitat: The tropics of South America

#### 4. Brazilian salmon pink birdeating tarantula

(Lasiodora parahybana)

Leg span: Up to 25 cm

Habitat: Atlantic Forest, Brazil

#### 5. Purple bloom birdeater

(Pamphobeteus insignis)

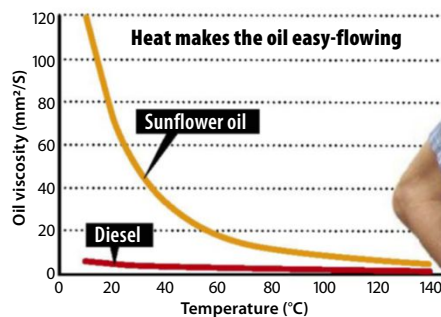
Leg span: Up to 22 cm

Habitat: Wet forests of Colombia

PETRA & WILFRIED

## CAN COOKING OIL POWER A CAR?

In 2013, Danish student Jeppe Lykke Hansen and three friends drove the 17,300 km from England to Mongolia in a Skoda Fabia powered by vegetable oil. The Skoda was originally diesel-powered, but the engine was modified to heat and filter the oil. The heating was necessary in order to lower the viscosity of the oil, making it sufficiently thin and pure. The engine was a two-tank system, in which a little diesel heated the sunflower oil, so it could be used to power the car.



Vegetable oil must be heated before use in an engine. Sunflower oil has the same viscosity as diesel at 140 °C.

Jeppe Lykke Hansen's converted Skoda was primarily powered by sunflower oil.

JEPPE LYKKE HANSEN



**Did you know** that the tailless tenrec from Madagascar has 29 teats, making it the mammal that can give birth to the biggest litter of young?

## HOW IS THE NUMBER OF GALAXIES CALCULATED?

**I have read that the universe holds 500 billion galaxies. But just how did physicists, astronomers and cosmologists calculate this number?**

The estimates of the number of galaxies in the universe are based on images from the Hubble Telescope, which can look further into the universe than any Earth-based telescope. Astronomers aim Hubble at a part of the sky and make it collect light from it for hundreds of hours.

The astronomers know the size of the area, and by counting the number of galaxies in the image and multiplying, they can estimate the total number of galaxies in the universe. Naturally, the method only works if the entire universe corresponds more or less to the small area in the image. But the very idea that the universe is "isometric" - the same in any direction - is one of the basic assumptions of cosmology. It could one day be proven wrong, but for now we stick with it!

The number of galaxies is calculated by counting those in a small area of the sky and multiplying.

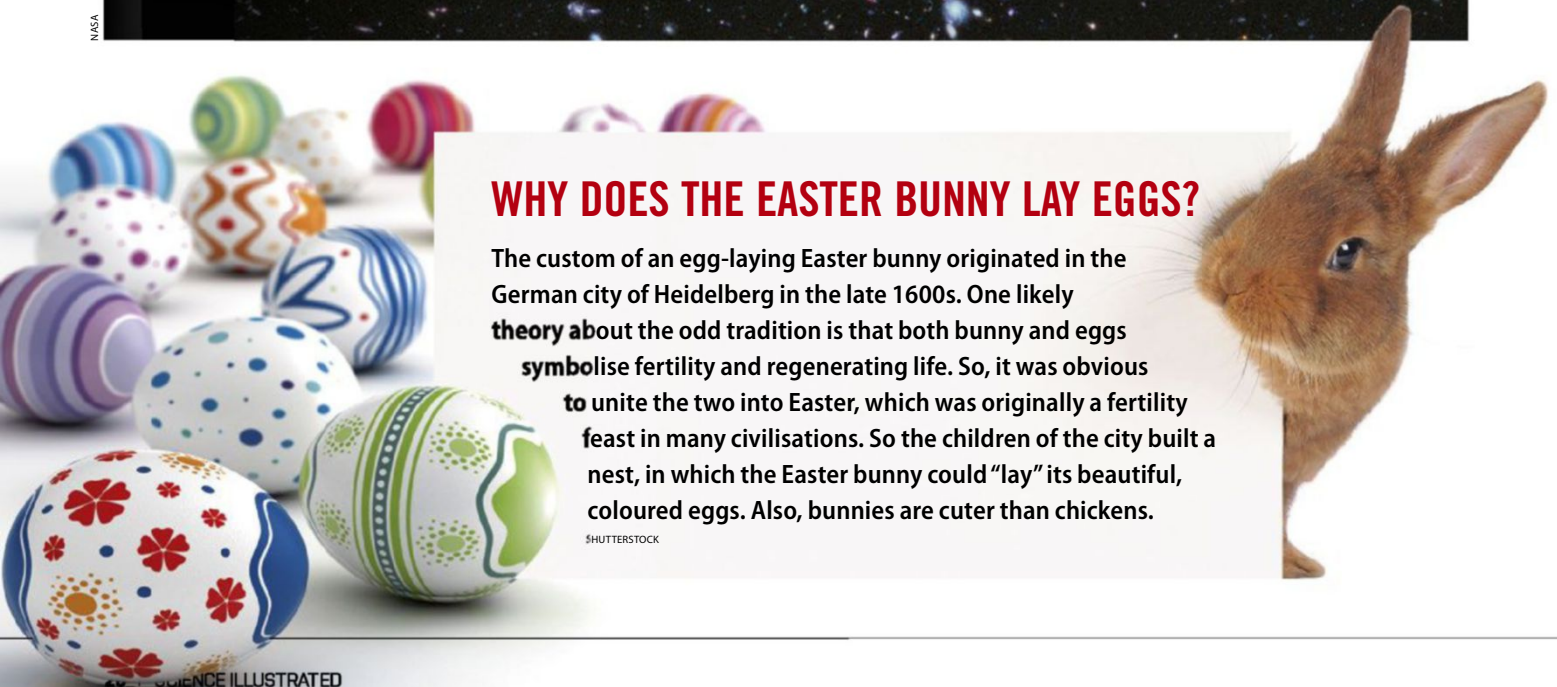
### ASTRONOMICAL NUMBERS (ESTIMATES):

- Number of galaxies in the universe: 500,000,000,000
- Number of stars in the Milky Way: 100,000,000,000
- Number of stars in the universe: 10,000,000,000,000,000,000,000,000

## WHY DOES THE EASTER BUNNY LAY EGGS?

The custom of an egg-laying Easter bunny originated in the German city of Heidelberg in the late 1600s. One likely **theory** about the odd tradition is that both bunny and eggs symbolise fertility and regenerating life. So, it was obvious to unite the two into Easter, which was originally a fertility feast in many civilisations. So the children of the city built a nest, in which the Easter bunny could "lay" its beautiful, coloured eggs. Also, bunnies are cuter than chickens.

SHUTTERSTOCK





How long are the mid-ocean ridges?

Underwater ridges in the Atlantic, Indian and Pacific Oceans make up the world's longest mountain range system. They stretch

# 65,000 km

## INSIDE THE BODY



### WHY DO WE BLUSH? AND WHAT HAPPENS?

Blushing is due to an expansion of the tiny blood vessels of the skin and is a reaction triggered by the autonomic nervous system, which we cannot control. We blush when we feel insecure, scared, or embarrassed. Before we developed language, blushing was probably an important signal, revealing mood and emotion.



The pointed bottoms of the amphorae made them easy to stack in dense layers in the holds of ships.

SHUTTERSTOCK & CLAUUS LUNAU

### WHY DO AMPHORAE HAVE POINTED BASES?

The Ancient Greeks and Romans used amphorae for transport and storage of wine, oil, and fish sauce. For stacking purposes during sea voyages of several hundred kilometres, the amphora bases were pointed, allowing the upright containers to be stacked in layers, one layer functioning as the base of the next one. Many amphorae were almost a metre tall and weighed over 50 kg when filled, but thanks to their pointed bottoms, they were still easy to handle.

By placing one hand on the neck of the amphora and the other under its pointed bottom, the person carrying the amphora could control the container, when contents were to be poured into another vessel.

CLAUUS LUNAU

**3.** As the blood vessels expand, more blood flows through them, making the skin of the face, and in some cases of the throat, breast and neck blush.

**2.** Via nerve fibres, the sympathetic trunk tells the blood vessels of the external skin layer to expand.

**1.** If we feel shy or embarrassed, the sympathetic trunk, a part of the autonomic nervous system, is activated. It is a nerve string located close to the spine, which starts right below the skull, continuing down to the tailbone.

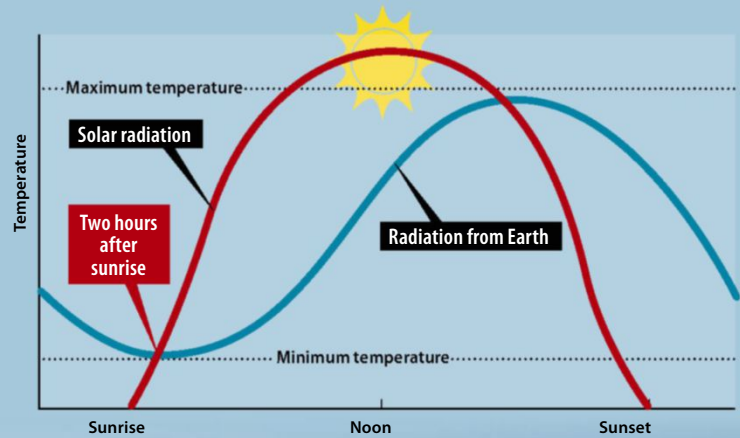
Sympathetic trunk



## Does it get a bit colder at sunrise?

Yes, the temperature often falls during the first few hours after sunrise. For how long and how much depends on weather, geography, and season.

"Temperature" is really just the amount of energy in the air. The atmosphere loses energy in the form of radiation to the universe. Radiation takes place throughout the day and the night. But the atmosphere also receives energy in the form of radiation from the Sun, but only when the Sun is shining. The temperature falls when more radiation is lost than received, which is the case for a couple of hours before sunset, all through the night, and until a couple of hours after sunrise.



### The temperature rises after two hours

Temperatures won't rise until the amount of sunlight received is greater than the radiation lost. The temperature drops during the night, and won't rise again until one or two hours after sunrise.



Although the Sun is up, the temperature continues to fall due to thermal radiation lost to space.

SHUTTERSTOCK

## DID THE SPACE SHUTTLE PARACHUTE MATTER?

The space shuttles landed in the same way as gliders, only at a rather higher speed of 355 km/h. To reduce the wear on brakes, and to allow the space shuttle to land on a short runway, the use of braking parachutes became the standard in 1992. The

parachute had a 12 m diameter and was used in 84 of 133 space shuttle landings. Each time, the parachute functioned exactly as intended.

NASA



### IN SHORT

#### HOW BIG ARE GPS SATELLITES?

A GPS satellite is the size of a small car and weighs 1,075 kg. The satellites orbit Earth at an altitude of 20,200 km and are positioned to ensure that at least four GPS satellites are always visible from any spot on Earth.



Which container port is the busiest?

The port of Shanghai, China, links the ocean and the Yangtze River. The number of standard containers or TEU passing through Shanghai annually is

# 32.5 million

## SPECIAL EFFECTS

# Could the T. rex see prey that stood still?

**In Jurassic Park, palaeontologist Alan Grant and two kids outsmart a T. rex by standing still. Could the dinosaur really only see motion?**

All modern research results indicate that the Jurassic Park dinosaur expert Dr. Grant and the two kids would have been eaten, as top predators such as the T. rex had very well-functioning vision. Studies of the cavity left by the brain in the skull show that the T. rex had a very large olfactory centre and so must have had a sophisticated sense of smell – which would have been more than sufficient to spot Dr. Grant and the kids.

Beyond smell, the T. rex had eyes the size of grapefruits. In addition, the shape of the skull demonstrates that the eyes were pointed forwards, so the T. rex had binocular vision, so it was able to judge distances and produce 3D images. Modern animals featuring binocular vision have no problems seeing prey, no matter whether it stands still or moves.

The T. rex had splendid vision and smell, so Dr. Grant and the kids would have been doomed.

### 3D PROJECT REVEALS DINOSAUR SENSES

The DinoMorph project began in 1994 with the aim of producing 3D models of dinosaurs based on measurements and scans of skeletons. The results show that the eyes of a T. rex were the size of grapefruit, could judge distances, and were able to see 13 times more clearly than the human eye.





**F**or years, a small frozen moon far away from the life-giving heat of the Sun has been a favourite among scientists as one that could support life. Beneath a thick ice layer, Jupiter's moon Europa has a huge ocean, in which life could thrive, if the ice does not prevent vital molecules from getting there.

Now, two astronomers have found evidence that Europa has an ice-cold version Earth's plate tectonics. The ice tectonics does not only make the moon more similar to Earth, it also increases the potential of finding life.

The tectonics functions as a huge belt conveyor, that can carry vital organic molecules from the surface to Europa's subsurface ocean. All at once, finding life had become much more likely.

#### **EUROPA'S SURFACE IS YOUNG**

The discovery was made by geologist Simon Kattenhorn and UK astronomer

Louise Prockter, who originally aimed to answer a totally different question that has bothered astronomers for years.

The question came up when the first probes reached Jupiter in the 1970s and found that the planet's moons are far from ordinary. Io, for instance, is the most volcanically active world in our Solar System, Ganymede is the biggest moon, and Callisto has the oldest surface. But the

most surprising discovery was Europa, which was not at all the dead ice ball that we had expected.

Most worlds are covered with craters, which were created during millions of years

of bolide strikes, whereas Europa's surface was young and smooth. As the moon is four billion years old, the surface must have therefore be continuously renewed.

Earth also has very few craters, as plate tectonics continuously blurs the surface. External, stiff plates move into the softer layer below them, where they are dissolved. In other places, the soft material is ►

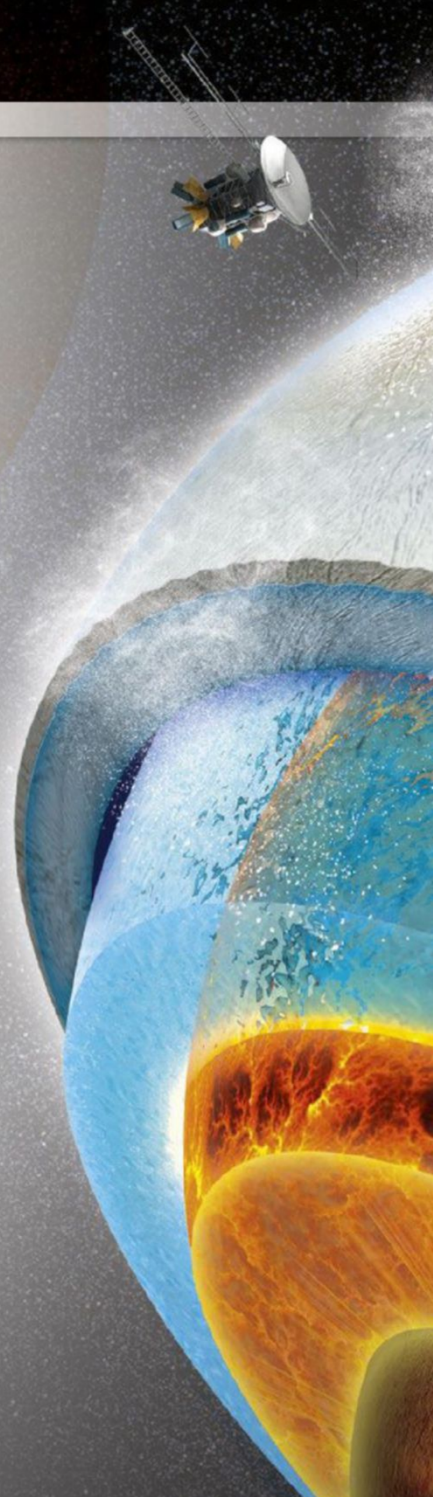
**“ Europa may not be the dead ice ball scientists had expected.”**

**For the very first time, scientists have confirmed plate tectonics on a different world than Earth. The discovery means that the ice moon Europa has become astronomers' best shot at finding extraterrestrial life.**

By Rasmus Kragh Jacobsen

## **BENEATH THE ICE:**

# **THE SECR**





**The atmosphere** of Europa is thin, mainly consisting of oxygen.

**The temperature** on the surface is approximately minus 160 °C.

**The ice cap** is between 3 and 30 km thick and would protect any life against radiation from space.

**Europa's diameter** is 3,122 km, which is 25 % of Earth's 12,742 km.

**The subsurface ocean** is an average of 100 km deep. The average on Earth is 4 km.

**The outer core** is made of rock, that may be volcanically active. The inner core is made of iron.

## SMALL WORLD HAS ICE CONTINENTS

Plate tectonics turn the moon's sterile ice cap into a conveyor belt, which can supply life for the huge subsurface ocean.

CLAUS LUNAU

**3** The ice plate melts and is squeezed together with the light, warm mass of ice, and move upwards.

**2** The heavier ice plate is forced under the lighter ice plate.

**1** Motion in the lower, warmer ice causes the ice plates to collide.

# ET WORLD



# 3 MISSIONS TO EXPLORE THE ICE MOON EUROPA

Europa is the top priority of the European and the American space agencies, ESA and NASA. A mission to Europa is the only way in which to collect information that can reveal whether the huge subsurface ocean includes living organisms.

ESA & NASA

JUPITER

EUROPA

NASA

**PROBE: Europa Clipper** ★ Launch 2025

## Probe will pass Europa 45 times

The Europa Clipper is going to try to find out whether Europa could include life by measuring the thickness of the ice cap and analysing the chemicals of the surface and in the atmosphere.

The probe will orbit Jupiter and pass by Europa 45 times at distances varying from 25 to 2,700 km. The orbit around Jupiter protects the probe against long

interaction with Europa's intense radiation belt, which would destroy the electronics aboard the probe relatively fast. In that way, the mission can last longer.

The probe brings a series of instruments. A radar to penetrate the ice and map out its thickness and an infrared spectrometer to study the materials on the surface. Moreover, cameras will map out the surface topography of hills and valleys and the temperature and chemicals on the surface.

The Europa Clipper probe will orbit Jupiter for at least 3.5 years.

CLAUS LUNAU

### EUROPA CLIPPER

- Who: NASA
- Duration: 3.5 years
- Type: Orbit
- Price: \$2.4 billion

A radar measures the thickness of the ice and checks if pockets of water exist inside the ice.

A mass spectrometer determines the chemical make-up of the atmosphere.





esa

**PROBE: Juice** ★ **Launch 2022**

## Touring Jupiter's ice moons

JUICE will visit Jupiter and its ice moons Europa, Callisto, and Ganymede. On Europa, which the probe passes twice, it will measure the thickness of the ice cap and map out the surface in detail, revealing the moon's internal structure and chemical environment.

The probe will explore the moons for at least three years, observing them by means of a broad range of instruments such as cameras, altimeter, radar, spectrometers, and radio instruments.

The ESA probe JUICE passes by Europa twice on its mission to Jupiter.

ESA



### JUICE

- Who: ESA
- Duration: 3 years
- Type: Orbit
- Price: \$1.4 billion

► forced upwards, producing new crust.

But this geological activity has only been proven to exist on Earth, and the question that has confused astronomers is how Europa renews its surface.

## GALILEO PROBE DISCOVERED OCEAN

In the late 1990s, when measurements from the Galileo probe revealed that Europa's ice cap probably covers a huge ocean, astronomers were thrilled.

The ocean most likely holds twice as much water as Earth's oceans combined. The pressure of Jupiter's gravity heats the ocean and keeps it liquid, and Europa's thick ice cap protects the ocean against Jupiter's lethal radiation.

In 2013, astrobiologists discovered that the surface includes minerals from comets and more, which typically contain simple organic building blocks and chemicals, which can provide energy for living organisms, if any exist there.

**“a stiff ice plate had broken in two pieces, which were being pushed apart.”**

Collectively, the discoveries meant that Europa's subsurface ocean met all the requirements for life. However, the moon's dense ice cap functioned as an impenetrable cover preventing the vital ingredients from reaching the ocean. And scientists still did not know why the moon's surface was only 40-90 million years old.

## IMAGES SHOWED BANDS OF NEW ICE

In the images from Galileo, Simon Kattenhorn and Louise Prockter found part of the explanation.

The images showed how a stiff ice plate had broken in two pieces, which were being pushed apart by a 20-30-km-wide band of ice. The scenario is reminiscent of places on Earth in which new material for the crust pushes the plates apart.

In other words, the scientists had found indications that new crust was created. However, nothing seemed to indicate ►

NASA

**ROBOT: Valkyrie** ★ **Launch 2025**

The probe-based robot will drill down through the ice.

CLAUS LUNAU

## Robot to explore the subsurface ocean

Valkyrie is an automatically controlled robot, which will drill its way through Europa's ice cap to explore the subsurface ocean.

The robot consists of a long, slim tube including instruments and jet engines that will force the robot down through the ice. A powerful laser on the surface is linked to the robot via an optic cable. The light will heat a chamber inside the robot which will melt the ice. Experiments have shown that Valkyrie moves through ice at a speed of almost 1 m/h.

### VALKYRIE

- Who: NASA
- Duration: Unknown
- Type: Lander
- Price: Unknown

A topographic camera maps out the level differences of the surface.

A thermal camera measures the surface temperature.

An infrared spectrometer explores the chemical make-up of the surface.



MERCURY

VENUS

EARTH

MARS

JUPITER

EUROPA

SATURN

- Diameter: 6,792 km
- Temperature: -63 °C
- Water: Yes, in the form of ice
- The right chemistry: Yes

NASA

## 1 ★ Mars

### Polar ice protects remnants of life

Mars actually has more dry land than Earth, but its atmosphere is much too thin to protect living organisms from space radiation. Nevertheless, life could exist on Mars. Data from the many probes and rovers that have visited Mars indicate that the planet was previously very similar to

Earth. Water flowed on the surface of the young Mars, and volcanic activity could have brought the building blocks of life from the surface to the interior of the planet. Though the surface is now dry and arid, microbes from the young planet may exist in polar ice and right below the surface.

MARS

Living organisms may have survived in the ice near the poles.

NASA

## 2 ★ Enceladus

Geysers attest to a big, subsurface ocean.

NASA

### Life hides in subsurface ocean

Saturn's moon Enceladus resembles Europa, as it also features an ocean below a thick ice cap.

Astronomers recently discovered 100+ water vapour and ice geysers on the moon by analysing images from the Cassini probe, which is exploring Saturn and its moons right now. The probe previously proved that building blocks of life such as carbon and hydrogen exist along with a core made of liquid rock.



# 3 OTHER WORLDS MAY HOLD LIFE

The search for life in other parts of the Solar System has begun. Astronomers have three favourites apart from Europa.

NASA

## ENCELADUS

- Diameter: 499 km
- Temperature: -222 °C
- Water: Yes, below the ice
- The right chemistry: Yes

NASA

## TITAN

- Diameter: 5,150 km
- Temperature: -179 °C
- Water: Yes, in the form of ice
- The right chemistry: Yes

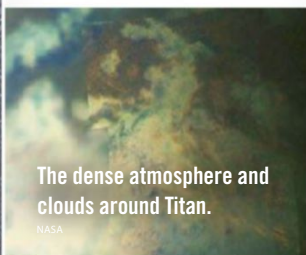
NASA

## 3 ★ Titan

### Atmosphere with the building blocks of life

The Titan moon orbits Saturn and is the most Earth-like moon in our Solar System, with oceans, lakes, and rivers on its surface. Instead of liquid water, they hold liquid hydrocarbons: methane and ethane.

Titan boasts clouds and a dense atmosphere including ingredients that scientists associate with life, such as methane. So, living organisms may restore the moon's atmosphere just like on Earth.



The dense atmosphere and clouds around Titan.

NASA

- ▶ that the old crust was swallowed again. So, Europa should grow. But it does not.

### SCIENTISTS CUT UP EUROPA

Subsequently, the two scientists decided to reconstruct the history of the surface.

In order to observe the motion of different areas, they cut the images of Europa to pieces, removed the bands of recently formed ice, and reunited the pieces.

The characteristic red lines on Europa's surface should continue from one clipping to the next. But they did not in all places. In one case, the lines stopped, and a region of approximately 20,000 km<sup>2</sup> had apparently disappeared without a trace. The region had probably moved beneath another plate in a wide zone. In a 115-km-wide area of the overlying plate in the subduction zone, there was a series of 100-m-high ice volcanoes, where the tension forced meltwater up through holes and cracks in the surface.

**“a region of 20,000 km<sup>2</sup> had disappeared without a trace.”**


Europa's plate tectonics resembles Earth's, and although scientists are still in doubt about the exact process, it has great astrobiological consequences. The plates move slowly, but surely from Europa's surface into the ice cap, where the included materials will finally end up in the subsurface ocean.

### NEW MISSIONS PLANNED

From studies of Antarctica, etc., scientists know that life can easily exist under such extreme conditions.

In August 2014, a US team of scientists drilled into the ice of Antarctica and proved the existence of lots of life in spite of the cold and huge pressure. The team found a complex microbiological ecosystem consisting of bacteria, which feed on rock.

Similar life forms could easily be found on Europa, but that would require a mission, which is luckily coming up.

Both NASA and ESA have missions to Europa in the pipeline. Apart from two space probes, which will measure the depth of the ice cap and map out the chemistry of the surface, NASA is constructing a robot that can drill through the ice. Hopefully, the combined missions will be able to answer the question of whether there is life on Europa. 



# MOUNT

## The eruption that

200 years ago, Mount Tambora exploded. 12,000 people were killed in an unprecedented inferno, and 250,000 died in flow-on events. Some day, maybe soon, that disaster, or one like it, could be repeated, and this time, the death toll will be counted in millions.

US DOD & CLAUS LUNAU

By Niels Hansen

Up to 100 km<sup>3</sup> of lava, ash, and sulfur was ejected out of Mount Tambora in a 44-km-high column.

### DELAYED MONSOON

Summer crops die in the drought. Autumn crops drown.  
**India**

### EXTREME COLD

Trees, crops, and domestic animals freeze to death.  
**Northern China**

### MASSIVE FLOODING

Waste water and drinking water are mixed. A cholera epidemic breaks out.  
**South-West Asia**

### MOUNT TAMBORA

On 10 April 1815, Indonesian Mount Tambora exploded in spectacular fury. The boom was heard 2,500 km away.



# DOOM

## nearly ended everything

### HEATWAVE

Altered wind conditions cause record low sea ice range.  
**Arctic regions**

### JUNE FROST AND SNOW

Snow storms make harvest fail.  
**North-Eastern USA/Canada**

### STORMY WEATHER

Cooling of the subtropics forces the polar front south, causing more frequent storms.  
**United Kingdom**

### FAILED HARVEST

The worst famine of the 1800s.  
**Europe**

### EXTREME WEATHER

Exceptionally low ocean temperatures intensify global climate change.  
**Eastern Pacific**

### TYPHOID EPIDEMIC

Malnutrition worsens typhoid epidemic. 800,000 infected.  
**Ireland**

### COLD SUMMER

Frost in mountains.  
**Spain**

### FAILED HARVEST

Cold and lack of sunlight kill corn and wheat.  
**US east coast**

### LACK OF FEED

Lack of horse feed causes the bike to be invented.  
**Germany**

### MORE TROPICAL STORMS

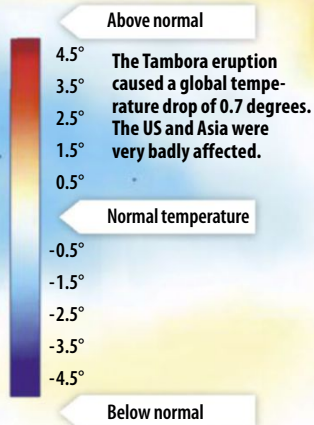
Altered ocean temperatures affect the weather.  
**Subtropical, North Atlantic**

### SEVERE DROUGHT

The rainforest under pressure.  
**Brazil**

## Tambora eruption left global marks

Cold, extreme weather, and failed harvests claimed some 250,000 victims throughout the world. The effect of the eruption was strongly felt the next year. Due to widespread cold, Americans and Europeans named 1816 The Year Without a Summer.





In 1815, the Rajah of Sanggar was a worried man. His small state on the northern peninsula of Sumbawa, Indonesia, is threatened. Pirates, slave traders, and tax collectors all try to get their share of the riches produced by the fertile land and its hard-working people.

So perhaps it is almost a relief to the Rajah, when, in the evening of 5 April, he has to instead turn his attention to the 4-km-high Mount Tambora volcano. An ear-splitting boom is followed by a column of glowing magma and ash, which rises 33 km into the air. For more than three hours, Mount Tambora spreads fear and dread in the area. And then, just as suddenly as it began, the eruption stops. Everybody breathes a sigh of relief, before beginning the hard work of removing ash from homes and rice fields.

If the tale had ended here, Sanggar may have existed today. But 5 April proved only to be a gentle breeze compared to the storm of destruction which Mount Tambora set off five days later, when the full and incredibly destructive eruption really began.

Soon, 12,000 people would lose their lives in lava flows, glowing avalanches, and thick drifts of hot ash, and up to 250,000 would die in the following months and years due to disease and famine. Throughout the world, ash and gases cause wild weather and extreme cold, leaving an indelible stamp on human art and culture.

## SURPRISING SUPER-ERUPTION

The Mount Tambora eruption on 10 April 1815 is the largest documented volcanic event in the world so far. The energy was comparable to the impact of a bolide measuring hundreds of metres across.

Nevertheless, the eruption was not extreme in comparison to the effect of previous – and future – volcanoes. According to a study from 2010, an eruption like Mount Tambora's or worse takes place every 780 years. In the Western World, there is a 10% risk of experiencing such an eruption in our lifetime.

Scientists know of over 1500 active volcanoes above sea level. The majority are located where two tectonic plates collide. Typically, one plate moves under the other, disappearing into the geological layer known as Earth's mantle. When the lower plate is heated at a depth of 50-100 km, water that was otherwise bound in sediments is released. The water moves up towards the ►

### ASH FALL

Reach: 700-800 km

Near the volcano, up to 1 m of ash may fall per hour. The ash makes people choke and collapses homes.

### BOMBS

Reach: 5 km

Volcanic bombs are large lumps of hardened magma. They weigh from 1 kg to several tonnes and kill people on the volcano.

# Water vapour set off history's worst inferno

Groundwater came in contact with Mount Tambora's magma chamber, increasing the pressure inside the volcano to extremes. After about 24 hours of eruption, Mount Tambora went berserk.

CLAUS LUNAU

### LAHAR (MUDSLIDE)

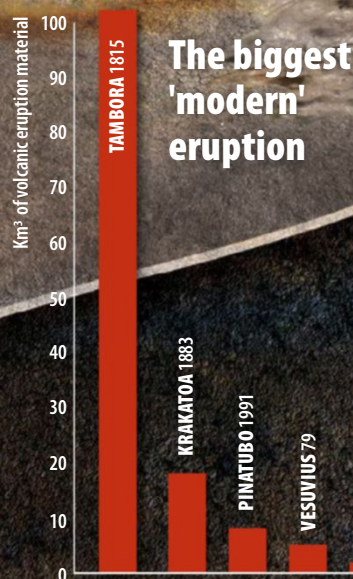
Reach: 5 km

Lahars are volcanic material mixed with water, which flow at a speed of some 60 km/h. The water is either rainwater or melted snow and ice.

### ASH AVALANCHES

Reach: 3 km

Lots of ash falls around the crater, making the volcano's slopes steeper. Finally, sliding ash buries everything.



# 1

**The Tambora eruption began when the magma below the volcano came in contact with groundwater.**

Magma that meets water results in an explosion, as the water turns into vapour. Vapour takes up some 1,600 times more space than water, so the pressure in the magma chamber quickly increases. It is neutralised in an explosive eruption.



## CALDERA COLLAPSE MADE TAMBORA GO BESERK

### ACID RAIN

Reach: 50 km

Volcanic gases react with oxygen or water vapour, producing sulfuric acid.

### ERUPTION COLUMN

Reach: global

When the Mount Tambora eruption began, a column rose 44 km into the air.

### LAVA FLOW

Reach: 10 km

Thick flows of 800-1,200 degree molten rock ignite anything in their way, and cover huge areas.

### FUMAROLAS

Reach: 1 km

Openings, from which hot, toxic vapour is emitted. Gas scalds people nearby or makes them suffocate.

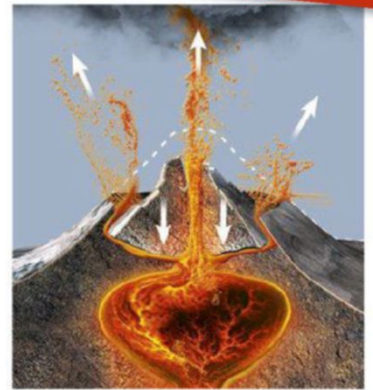
GROUNDWATER

MAGMA CHAMBER

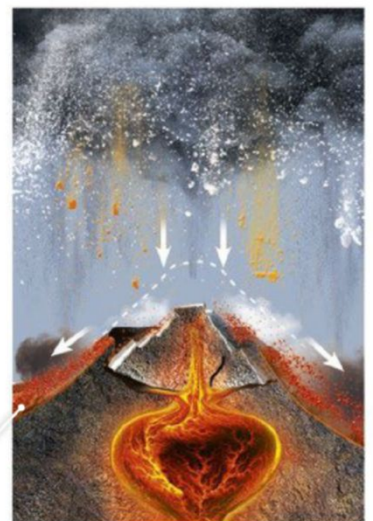
### GLOWING AVALANCHE

Reach: 20 km

When the eruption column collapses, 400-degree-hot ash, magma droplets, and acid gases flow down the volcano's slopes, destroying everything.



**2** After 24 hours of constant eruption, the magma chamber had lost so much material that the "roof" above the huge cavity could no longer support itself. The pressure could not do the job either, and **the top 1.5 km of the volcano started to collapse into the magma chamber.** It was like stepping hard on a ketchup bottle: The magma spouted out under high pressure. This phenomenon is known as a caldera collapse.



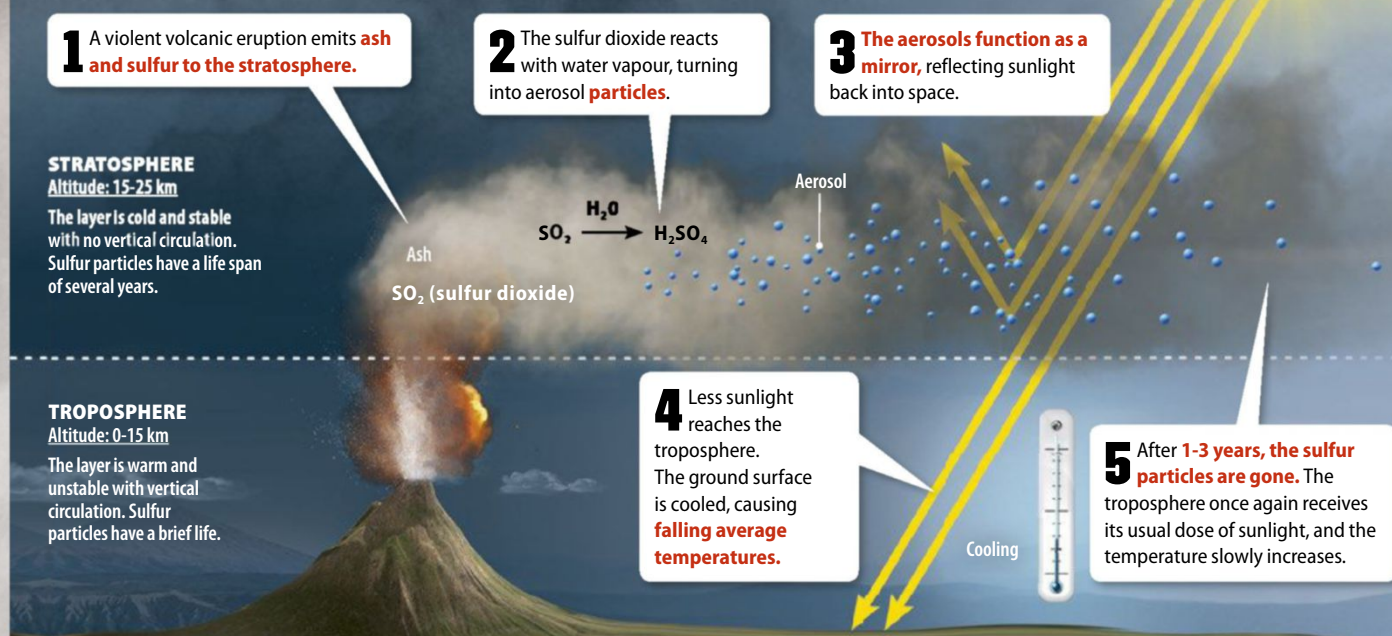
**3** The huge amounts of magma meant that the supplies for the eruption column of hot gases above Mount Tambora were repeatedly and abruptly cut off, **making it collapse over and over again. Millions of tonnes of ash and molten rock fell down on the volcano, producing glowing avalanches.**



# 1816: The Year Without a Summer

Sulfur compounds in the volcanic gases pose a major threat to the climate. If the eruption is so powerful that the sulfur reaches the stratosphere 15-25 km above Earth, droplets of solar-reflecting sulfuric acid will be produced.

CLAUS LUNAU



► upper plate, where it lowers the melting point of the rock. In the process, magma is produced, which continues up through Earth's crust. If the magma reaches the surface, a volcano is formed – typically of the explosive type like Mount Tambora.

Scientists seek map out the stress points of the 1,500 volcanoes that present a looming disaster. But that is not an easy task, as historical data are not much of a help. Volcanoes which recently erupted are of course not the most dangerous ones. Mount Tambora will probably not be responsible for the next great disaster. Actually, there is a direct relationship between the time passed since a volcano's most recent eruption and the scale of the next eruption.

A volcano may produce two minor eruptions a few years apart, but according to Elizabeth Cottrell of the Smithsonian Institution, at least 100 years – and often both 1,000 and 10,000 years – pass between

individual volcanoes' Tambora-like enormous eruptions. So, she concludes, that statistically, we cannot rule out any of the world's active volcanoes being responsible for a major eruption.

## VOLCANOES - A BLESSING AND A CURSE

Cottrell is an expert on the social effects of volcanic eruptions, and in a study from 2015, she compares population density and volcanic activity.

The conclusions are shocking. Over 200 million people live less than 30 km from an active volcano, and so, their lives are in immediate danger in the case of even a limited eruption. Within a radius of 100 km, where you are nowhere near being safe during a violent eruption, the number of people at risk is 750 million.

Of course, people are not too stupid to realise that volcanoes are hazardous, but a

volcano in the neighbourhood also gives lots of advantages. The risk of eruptions is a drawback, but on the other hand, volcanic soil is very fertile and produces high crop yields.

Moreover, people can take advantage of hot springs or drill for geothermal energy. That is done in Iceland, which depends 100 % on alternative energy production sources. The mineral-rich water from volcanic sediments is also attractive, as it sometimes creates gemstones or generates various other valuable raw materials.

## SULFUR MESSES UP THE CLIMATE

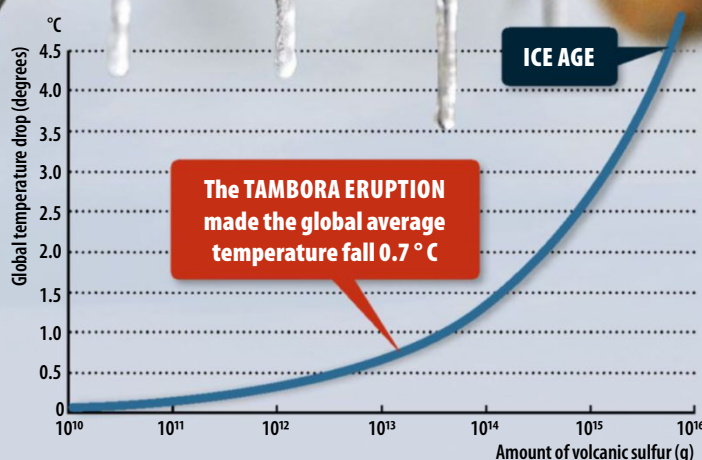
Although geologists have become good at warning the locals before an eruption, we can do nothing to prevent the long-term effects. Volcanic sulfuric acid droplets in the stratosphere reflect part of the incoming solar radiation, and the result is global cooling.

Scientists have recreated Mount



## The cooling effect of volcanoes on Earth

Geologist Haralður Sigurdsson has calculated to what extent the temperature drops on Earth, depending on the amount of volcanic sulfur in the stratosphere. According to him, a sulfur-rich super-eruption could produce global cooling of 4-5 degrees - a temperature comparable to the peak of the most recent ice age.



Crops freeze during a volcanic winter. In 1816, sulfur from Mount Tambora blocked out the Sun, causing frost in the summer.

GETTY IMAGES

## Archaeologists found “the Pompeii of the East”

In 2004, geologist Haralður Sigurdsson and his colleagues of the US and Indonesia found a house with two charred bodies that was buried during the Mount Tambora eruption. They had suffered the same fate as

people near Mount Vesuvius in 79 AD. Now, the Sanggar village, known as “the Pompeii of the East”, is excavated. Only 26 of the approximately 12,000 inhabitants of the island of Sumbawa survived.

**Excavations have been carried out at the foot of Tambora since 2004.**

Tambora’s effects in weather models, which are also used to predict the future climate. The same has been done concerning a much more limited eruption by the Mexican El Chichón volcano in 1982. The maximum global cooling caused by Mount Tambora was 0.7 degrees, whereas El Chichón produced a temperature drop of around 0.2 degrees. On the other hand, El Chichón allowed scientists to study the behaviour of the cooling sulfur and conclude, for how long the volcanic cold can be expected to affect the world.

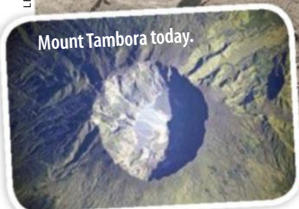
Weather balloon experiments showed that during the weeks following El Chichón, some 20 million tonnes of sulfuric acid were produced. About one year later, the atmosphere still contained 8 million tonnes. Simulations demonstrate that the sulfuric acid cooling effect peaks a year after the eruption and is almost gone after some four years.

The models also show that the global cooling remains for another few years, ►

LEW ABRAMS/UNIV. OF RHODE ISLAND



Mount Tambora today.

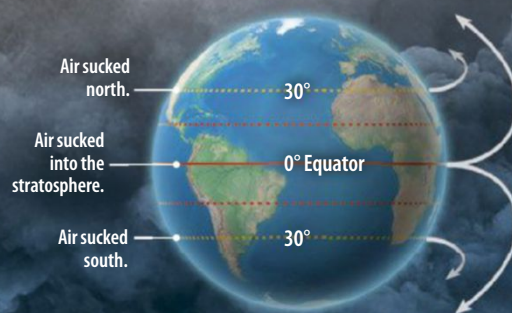




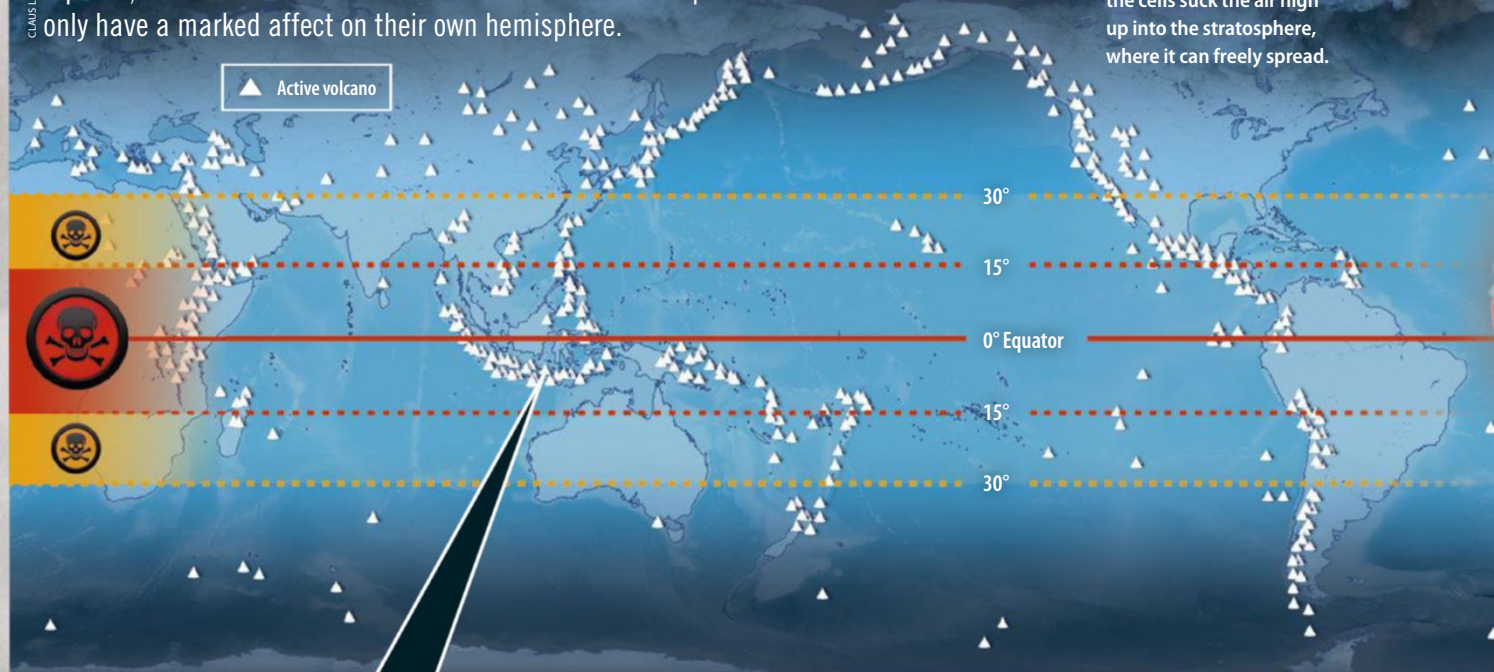
# Tropical volcanoes may paralyse the whole world

Only volcanoes in the tropics can have the same major consequences as Mount Tambora. The zone, in which a volcanic eruption can have a global effect, stretches some 15 degrees to each side of the Equator, whereas the two zones from the 15th to the 30th parallels only have a marked effect on their own hemisphere.

CLAUS LUNAU



**Atmospheric cells** divide the world. At the Equator, the cells suck the air high up into the stratosphere, where it can freely spread.

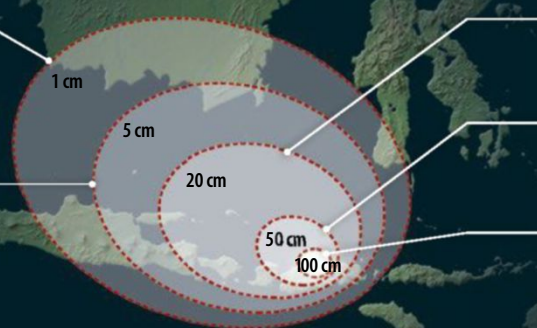


## Ash could kill millions

200 million people live less than 30 km from a volcano that has been active during the past 10,000 years. They will be in danger in case of a new eruption like Mount Tambora's.

**1 CM LAYER:** The ash pollutes drinking water and food, and the fine ash causes asthma, bronchitis, respiratory passage irritation, plus eye and ear injury.

**5 CM LAYER:** Crops die. Ash may absorb rain and make structures collapse. Sewers are blocked, and air transport is impossible. Overland transport is slow.



**20 CM LAYER:** Ordinary structures collapse. It is only possible to escape on foot. Relief work is impossible.

**50 CM LAYER:** Even massive structures collapse. Land evacuation and transport are impossible.

**100 CM LAYER:** Ash makes people suffocate. Volcanic bombs kill or injure people. Escape is impossible.





**NORTHERN HEMISPHERE AFFECTED** Eruption in the 15-30 degree zone sends sulfur particles north.



**GLOBAL EFFECT** A violent eruption in the 0-15 degree zone north/south of the Equator spreads sulfur particles worldwide.



**SOUTHERN HEMISPHERE AFFECTED** A violent eruption in the 15-30 degree zone sends sulfur particles south.

► because the ocean has cooled and must be heated again. And when the ocean is colder, the atmosphere is affected.

### BREADBASKET THREATENED

When scientists simulate the climatic reaction to a violent volcanic eruption, they include a certain amount of sulfuric acid in the models, but they can never know the exact amount of sulfur emitted by individual volcanoes. The quantity of sulfur compounds such as  $\text{SO}_2$  and  $\text{H}_2\text{S}$  in volcanic gases may vary from 1 to 10 %, so a minor eruption with sulfur-rich magma could have the same climate effect as a major eruption with sulfur-poor magma.


The simulations also show that the location of the volcano means a lot. If it is in the temperate or polar regions, the climate effect is very local.

The massive Laki eruption on Iceland in 1783 is an example. North-Western Europe was particularly affected, making the American ambassador of France, Benjamin Franklin, write the very first scientific article about the relation between volcanoes and climate.

But if the volcano is located in the tropics, an eruption could affect an entire hemisphere or even the whole world. That

was the case with both Mount Tambora and El Chichón. So, scientists can only really predict the global effect, when they know how much sulfur is involved in a major volcanic eruption. And the regional climate change cannot be calculated until scientists know the exact location of the volcano.

If the next super-eruption is more powerful than Mount Tambora's, there will be more doubt. Some scientists, such as geologist Haraldur Sigurdsson, estimate that global temperatures could fall five degrees, and that's almost like an ice age.

Claudia Timmreck of the Max Planck Institute for Meteorology is slightly more optimistic. According to her, the cooling will be 3-3.5 degrees. On the other hand, the cooling will not be evenly distributed. In 2010, Timmreck showed that the cold will mainly affect regions in between the polar and the tropical regions, which could be hit by a volcanic winter with temperature drops of some 12 degrees. So, an eruption will affect Europe, the US, and parts of Asia the most: densely populated areas, which are also the world's bread baskets. The risk is very real. 

## Volcanic history written in the ice

By counting the layers of ice cores drilled in Antarctica and Greenland, meteorologists have mapped out the volcanic eruptions of the past 1,500 years. The scientists looked for sulfur, confirming the eruptions and their effect.

YEAR	VOLCANO	GLOBAL SULFUR INCREASE*
1991	<b>Pinatubo</b> , Philippines	30.10
1982	<b>El Chichón</b> , Mexico	14.00
1815	<b>Tambora</b> , Indonesia	109.72
1783	<b>Laki</b> , Iceland	92.96
1600	<b>Huaynaputina</b> , Peru	56.59
1452	<b>Kuwae</b> , Vanuatu	137.50
1258	<b>Rinjani</b> , Indonesia	257.91
1176	<b>Krafla</b> , Iceland	45.76
541	<b>Rabaul</b> , Papua New Guinea	42.56

\* MEASURED IN MILLIONS OF TONNES

Ice cores from Greenland and Antarctica document the past 1,500 years of volcanic eruptions.

NIELS BOHR INSTITUTET





0-10 metres  
**BARNACLE**

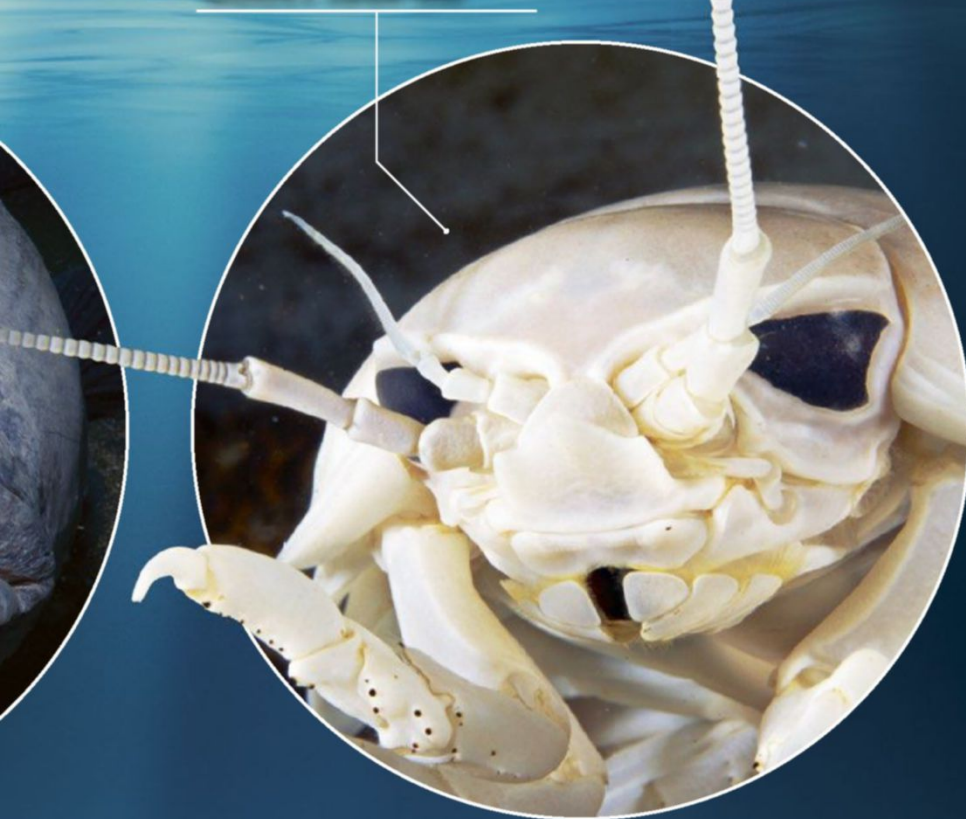


10-200 metres  
**WOLF FISH**

# Life on the Ocean



200+ metres  
**GIANT ISOPOD**



The benthic zone is one of the most mysterious places on the planet, yet it stretches unbroken from your local rock pools to the black, crushing depths. The creatures that live on the seabed are fascinating. Let's visit!

# Floor

By Lars Thomas. Art: Mikkel Juul Jensen

## TIDAL ZONE 0-10 METRES

### From water to land and vice versa

Twice a day, the environment of the most extreme ocean zone changes between water and land – altering the temperature and oxygen content as well. When the water roars back and forth, it is important to hold on.

**Greatest challenge:**  
Flexibility

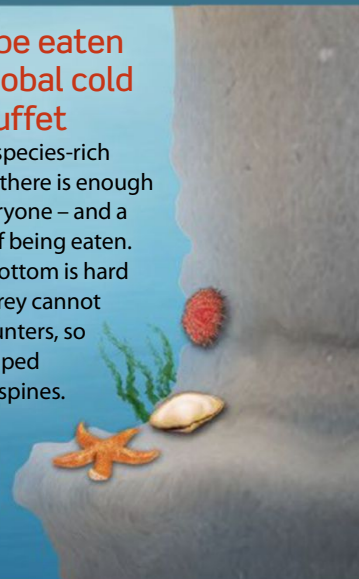


## SUNLIGHT ZONE 10-100 METRES

### Eat and be eaten at the global cold ocean buffet

In the most species-rich ocean zone, there is enough food for everyone – and a severe risk of being eaten. Where the bottom is hard and stony, prey cannot hide from hunters, so it has developed armour and spines.

**Greatest challenge:**  
Protection



## BENTHIC ZONE 100+ METRES

### Patient search for food and mates in the abyss

There are no plants and only a few animals, which must either feed on material coming from above or each other. Prey and mates appear so rarely, that many species must wait patiently and perhaps only eat and mate once.

**Greatest challenge:** Loneliness





# TIDAL ZONE

## DEPTH: 0-10 METRES



At ebb tide, the barnacle closes its tight-fitting cover to retain water.

SHUTTERSTOCK

## Barnacles grip with bio-superglue

A glue that beats artificial products allows the small crustacean to survive in the tough tidal environment.

The creatures living on the floor of the tidal zone must solve two problems to survive. Due to the waves, there is a constant risk of being swept away, and due to the tide, they may spend up to half their lives on dry land. Among the specialist survivors of troubled waters are barnacles, which are crustaceans.

The animals live in calcium shells, which stick to piers and rocks by means of an extremely efficient glue. Many scientists have fruitlessly tried

to copy the glue, which can both harden under water and is strong enough to hold the barnacle in position and disregard even the most powerful of waves.

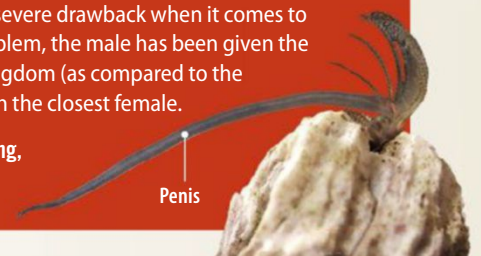
The barnacle shell features a calcium plate cover. As the water retreats, the barnacle closes the cover, which is so tight-fitting that the water inside the shell remains. As the water returns, the creature's legs come out, and it uses them to sift edible particles from the water.

## Barnacles have the world's longest penises

The barnacle's immobility is a severe drawback when it comes to reproduction. To solve the problem, the male has been given the longest penis in the animal kingdom (as compared to the creature's size) in order to reach the closest female.

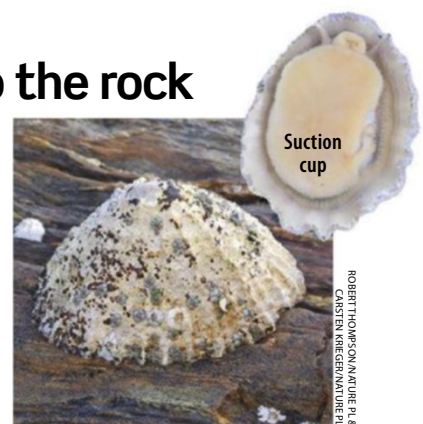
The male's penis is extremely long, so he can reach the female.

CHRIS NEUFELD/QUEST UNIVERSITY CANADA



## Odd snail clings to the rock

The common limpet, which is a type of snail, remains just as stuck to a surface as the barnacle, but for a different reason. The common limpet lives under a shell which is open at the bottom, and it sticks to the surface by means of a suction cup. The suction is so efficient that it takes 50+ kg to remove a 5-6-cm-long common limpet. At high tide, the animal crawls about, eating algae, but it always returns to the same place. The shell makes a groove in the rock, reinforcing the suction.



The cup allows the common limpet to suck very tightly to the surface.



**LIGHT:** Lots of sunlight and so lots of vegetation, particularly large seaweed plants.

**TEMPERATURE:** Highly variable, between 0 and 20-30 °C or more in shallow places.

**OXYGEN CONTENT:** Variable – high at high tide, but zero, when the coast is drained at low tide.

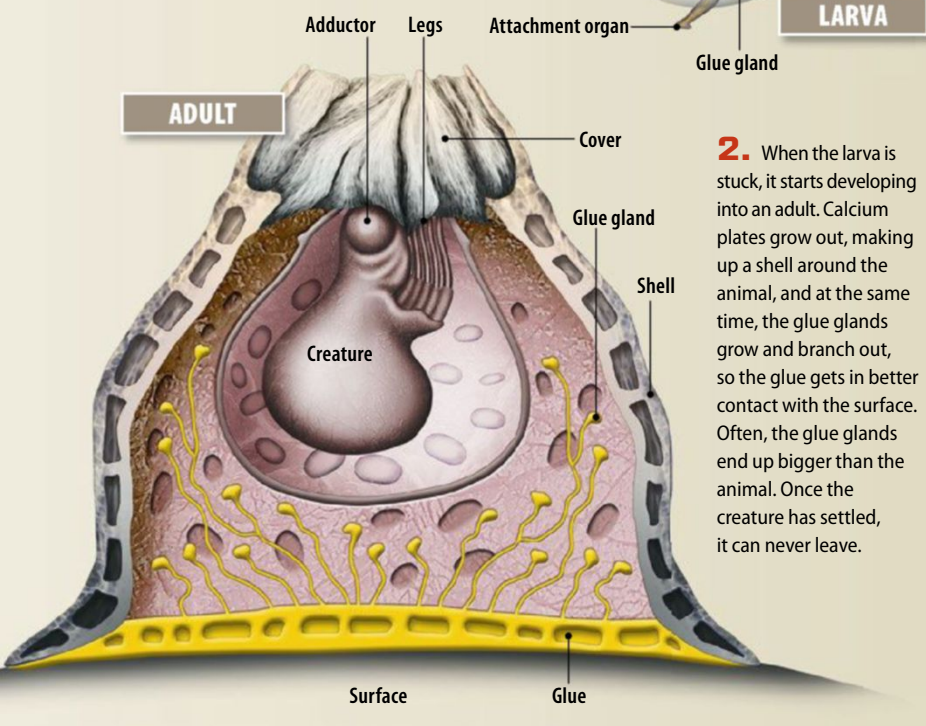
**WATER MOTION:** Very powerful due to waves and tide. The motion makes demands on the animals' ability to hold on or entrench themselves, so they are not swept away. The creatures' bodies must also be sturdy or protected by shells in order not to be crushed by the water.

SHUTTERSTOCK

## Larva has glue gun on its forehead

Barnacles begin their lives as free-swimming larvae, but after a while, they find a solid base to settle on. The shrimp-like animal sticks to the surface due to the "glue" from a gland on its forehead, producing a calcium shell.

**1.** As a larva, the barnacle has glue glands in its head, opening into an attachment organ on the forehead, which makes the first contact with the surface, when the barnacle is ready.



**2.** When the larva is stuck, it starts developing into an adult. Calcium plates grow out, making up a shell around the animal, and at the same time, the glue glands grow and branch out, so the glue gets in better contact with the surface. Often, the glue glands end up bigger than the animal. Once the creature has settled, it can never leave.



SHUTTERSTOCK

The mudskipper's gills can absorb oxygen from the air, if they are moist.

## Fish breathe with their entire body

Other fish follow the water as the tide retreats, but the mudskipper does not. The small fish, which lives in the mangrove swamps of the tropics, stays put, pretending to be a terrestrial animal. The mudskipper even flirts and mates in shallow waters. Like other fish, the mudskipper breathes through gills, but as long as the gills are moist, it can absorb oxygen directly from the air. The fish simply captures a large air bubble in the gill cavities, which can be hermetically sealed by means of the gill covers. Mudskippers can even absorb oxygen through their entire body surface, if only it is wet. When the water returns, the fish move into passages they dug in the mud, waiting for the water to recede again.

## Crabs fiddle at low tide

In the tropics, the overgrown claws of fiddler crabs light up the grey silt at ebb tide. Some 100 species of the charismatic crustacean exist, and they are common almost all over the world. The female looks like any other crab, but the male has a claw which is many times bigger than the other. As soon as the water retreats, the crabs come out of their tunnels in the ocean floor. The males fiddle with their huge claws to scare other males and attract females – a signal that would not be as efficient under the water.

The male's huge claw can attract females from afar and scare off other males.

TIM LAMAN/GETTY IMAGES





# SUNLIGHT ZONE

## DEPTH: 10-200 METRES

### Starfish turned inside out

In spite of its peaceful appearance, the starfish is an awesome hunter with a secret weapon. The animal's stomach can come out of its mouth to digest a mollusc inside its shell.

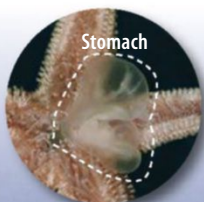
Starfish are among the oddest predators in the world. Lacking teeth, claws, and other sharp instruments, they have to kill their prey based on a totally different strategy. When a starfish finds a mollusc, it hugs the shell with its five arms. Each arm is equipped with hundreds of so-called suction cups,

that hold on to the mollusc shell. The starfish pulls, until the mollusc gets tired and unable to keep its shell shut. Even a narrow passage is enough to get the meal served. The peculiar hunter is equipped with an unusual stomach, which can be turned inside out and moved out of its mouth and through even the tiniest gap

between shells. Although the starfish turns its stomach inside out, so it appears outside its body, the creature's digestion is still functioning very well. The stomach enzymes immediately begin to dissolve the animal inside, until only the unbroken, empty shell remains.

#### Water used for suction

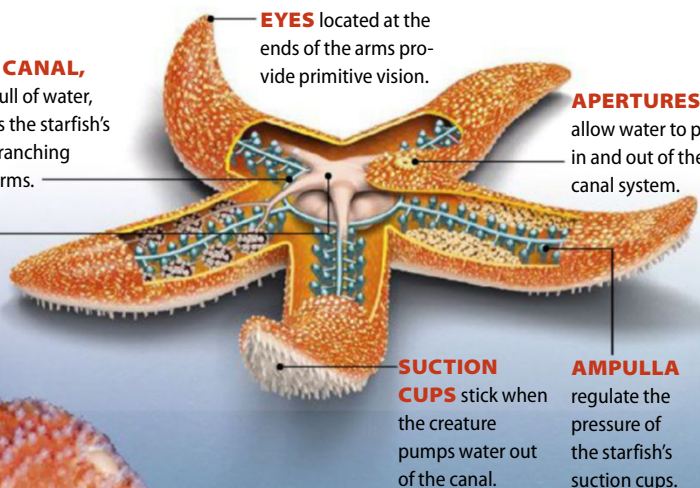
A system of canals inside the starfish allows it to move and stick mercilessly to its prey.



RODGER JACKMAN/GETTY IMAGES

**THE STOMACH** can be moved out of the mouth and forced through a shell gap. The prey is digested alive.

**A RING CANAL**, which is full of water, surrounds the starfish's mouth, branching into the arms.



**EYES** located at the ends of the arms provide primitive vision.

**APERTURES** allow water to pass in and out of the canal system.

**SUCTION CUPS** stick when the creature pumps water out of the canal.

**AMPULLA** regulate the pressure of the starfish's suction cups.

The starfish sucks and pulls, until the mollusc is too exhausted to keep its shell shut. One single suction cup does not suck very much, but the animal has hundreds of them.

WILD WONDERS OF EUROPE/LUNDGREN/NATURE PL



**TEMPERATURE:** In the tropics up to 30 °C at the top and 5-10 °C at the bottom. In arctic regions, temperatures may rise with depth – from about 0 °C at the top to 3-4 °C further down.

**WATER MOTION:** In the case of a storm, waves have a relatively deep reach. But at the very bottom, the conditions are more stable.

**LIGHT:** Is reduced with depth, but generally, there is enough light for both free-swimming plankton algae and stationary seaweed plants to grow. The plants are the base of an extensive ecosystem. More species live in the photic zone than any other place in the ocean.

## The Armoured Mollusc...

Many places in the sunlight zone, the ocean floor consists of rock or stones, making it difficult to hide from predators. Instead, many species have developed armour, but only a few have such solid armour as ocean quahog shells. The powerful mollusc, which lives in the North Atlantic, can grow 10+ cm wide, and a hammer is required to open the thick shell. The armour clearly offers good protection, as still-living, 500-year-old ocean quahogs have been found. However, one single predator has the instrument needed to end the mollusc's life.



The ocean quahog can only be opened with a hammer.

## ... vs the Terrible Teeth

The Atlantic wolf fish's teeth look as if they had been haphazardly thrown into its mouth, but its bite is a precision tool, which can easily open the shells of ocean quahogs. A big wolf fish is even able to cut a broom handle or a wooden lath in two, and careless fishermen may easily lose some of their

fingers, as even dead wolf fish can bite them off via reflex. The teeth are worn all the time, and so, the fish changes them at regular intervals. During those periods, it is unable to eat.



The wolf fish easily bites through an ocean quahog, but it must frequently change its worn out teeth.

FLORIAN GRANER/NATURE PL

## The sea urchin is a disgusting mouthful

Most predators think twice before they attack a sea urchin. In cold ocean regions, the sea urchin spines are relatively small and thin, but in the tropics, the sharply pointed spines can be up to 30 cm long, or 2-3 times longer than the animal's body. Each single spine is attached to a base on the shell of the animal and is linked with small muscle cells, so it can be turned in the direction where danger looms. Wolf fish and sea otters are among the predators that will not hesitate to bite, regardless of the spines.



The pointed spines can grow three times as long as the animal's body.

JOHN BORTHWICK/GETTY IMAGES

## DID YOU KNOW ...

Almost **3/4** of Earth's rocky surface is ocean floor

**60,000** mud shrimps live per m<sup>2</sup> of the Danish Wadden Sea floor and are eaten by millions of migratory birds.



ALEX HYDE/NATURE PL

### Ocean floor creatures have anti-freeze blood

In arctic and antarctic regions, many animals that live on the ocean floor produce glycoprotein, a type of anti-freeze, that protects against frost damage and allows movement at body temperatures below zero.

**4°C** is the constant temperature in most of the deep sea.

**1,000,000 t** of CO<sub>2</sub> are absorbed by deep sea fish annually in UK waters alone.

### Worms beat insects in biodiversity

According to one count, the ocean floor probably holds 10 million roundworm species. So, they are more species-rich than insects, of which an estimated 6-10 million species exist.

**30** times bigger than its relatives, this giant deep sea mollusc gets energy from sulphur-consuming bacteria in its gills.

DEEPEAPHOTOGRAPHY.COM





# BENTHIC ZONE

## DEPTH: 200+ METRES

### Modest pig eats mud

Sea pigs specialise in eating the only thing there is plenty of in the deep sea: silt. Unlike their relatives in shallower waters, the small group of deep sea cucumbers developed a number of thickenings that resemble legs. So, they can walk in an unhurried fashion across the ocean floor, as they gnaw through the top layer of mud. The creatures digest all organic particles and excrete everything else. The menu includes such different ingredients as dead plankton and aquatic plants, leftovers from other animals' meals, plus scales and fish faeces sinking down from high above.



DAVID WROBEL/SEAFARMS.COM

### Sea spiders' legs would break in any other place

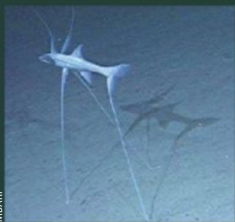
The environment at the bottom of the deep sea is the most stable on Earth. Not only are oxygen content and temperature unchanging, but storms that lash the surface have no effect down here, allowing the existence of one of the most delicate and fragile animals – the extremely thin and long-legged sea spider. In the troubled waters close to the surface, it would probably be torn apart in a matter of seconds. In spite of its delicate looks, the sea spider is a predator, which uses a special trunk to suck nourishment from stationary creatures such as sea sponges, sea anemones, or carcasses.

**A creature as delicate as the sea spider can only exist in the still waters of the deep sea.**

NORBERT WU/MINDEN PICTURES



### Tripod fish can mate with itself



The tripod fish rests on its fins.

All deep sea animals have a severe problem. Only very few exist in the sparsely populated environment, and many fish live their entire lives without ever encountering another of the opposite sex. The tripod fish has found a radical solution to the problem. If a mate never comes by, it mates with itself. The herring-like fish uses its prolonged fins to stand on the ocean floor, patiently waiting for food and mates.





ZONE  
FACTS

**LIGHT:** Very weak at moderate depths, none at great depths. As the animals live in darkness, many are blind or have rudimentary eyes.

**WATER TEMPERATURE:** Constantly around 4 °C.

**WATER MOTION:** Almost none.

**OXYGEN CONTENT:** Low.

**PRESSURE:** The pressure is high, growing by one atmosphere per 10 m. In the deepest parts of the oceans, the pressure is 1,000+ times as high as at the surface. Pressure is rarely a problem for the animals. Due to their high water content, they are not deformed.

# The deep sea garbage collector eats or starves for years

Dead animals and organic particles sink to the bottom, where they are consumed by deep sea scavengers. The greediest is the giant isopod, which has extreme adaptations to the varying availability of food.

In the darkness of the deep sea, no plants can grow, and so, scavengers are dominant among the creatures that live there. Some of them are very small and consume the organic particles that constantly sift down from above. But the giant isopod is in a league of its own. This 60-cm-long relative of the terrestrial woodlouse is an expert on cleaning up, when

dead whales, seals, or big fish end up on the deep sea floor. The giant isopod has an extraordinarily healthy appetite, eating more or less all the time, if plenty of food is available.

The garbage collector of the deep sea is surprisingly easy to keep in captivity. It thrives in a pool with very cold water, if fed fresh fish.

Such a stable supply of food is not necessarily available in the infertile deep sea, where dead whales are rare, and so, the giant isopod has adapted to survive for long periods of time without food. In aquariums, some individuals have survived for up to four years without food, probably by entering into a hibernation-like state.

The giant isopod sets out to clean up after dead seals and whales.

VISUALS UNLIMITED/NATURE PL

## Animals grow in the abyss

Small species can grow larger in the deep sea, where there are only a few predators to hide from. So, animals generally become bigger, the deeper the ocean they live in. Scientists call the phenomenon deep sea gigantism.

### RELATIVES AT THE SURFACE AND IN THE DEEP SEA

#### SHARKS

Surface: **Mud shark 1.2 m**

Deep sea: **Greenland shark 7.5 m**

**6**  
times  
as big

#### ISOPODS

Surface: **Isopod 3 cm**

Deep sea: **Giant isopod 60 cm**

**20**  
times  
as big

#### SQUID

Surface: **Squid 30 cm**

Deep sea: **Giant squid 15 m**

**50**  
times  
as big





# 1. GRAVITY

What you need to know, now

LESSON 2: RADIOACTIVITY

LESSON 3: MAGNETISM

LESSON 4: LIGHT

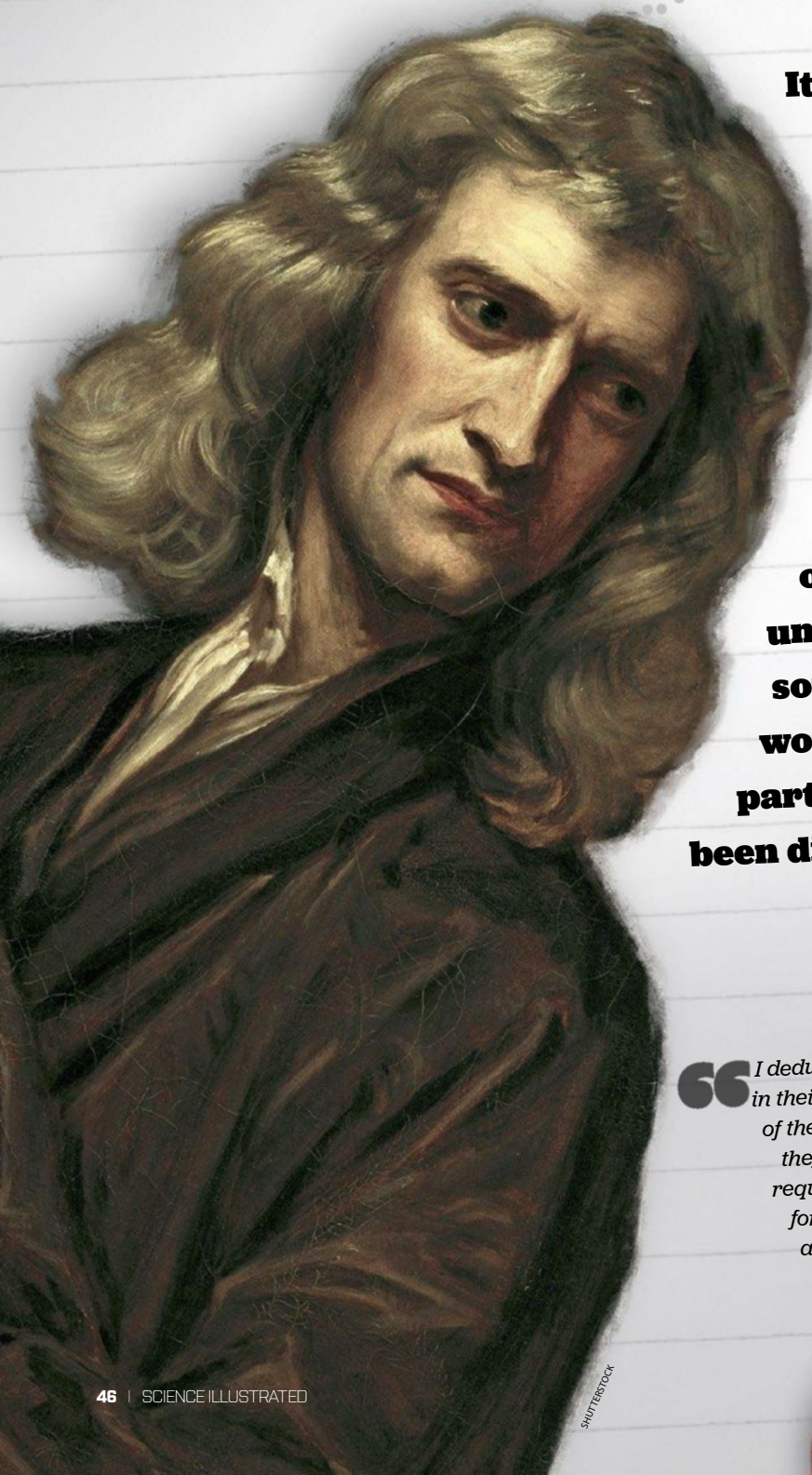
LESSON 5: TEMPERATURE

LESSON 6: SOUND

Our revamped Instant Expert section will teach you the fundamentals of the universe in just 10 minutes!



By Rolf Haugaard Nielsen



It affects you, as you hike up a hill, produces tidal waves in the oceans, and keeps Earth in its orbit around the Sun. **Gravity** is probably the most well-known of all forces of nature. Yet for physicists, it remains one of the most poorly understood. According to some theories, gravity may work by the exchange of particles that have not yet been discovered.

“I deduced that the forces which keep the Planets in their Orbs must be reciprocally as the squares of their distances from the centres about which they revolve: & thereby compared the force requisite to keep the Moon in her Orb with the force of gravity at the surface of the Earth, and found them to answer pretty nearly.”

Isaac Newton





# 9.81 M/S<sup>2</sup>

*Standard (acceleration due to) gravity*

**STANDARD GRAVITY** is defined as 9.80665 m/s<sup>2</sup> at the surface of the Earth. This means that all freely falling objects, big or small, light or heavy, will experience this constant acceleration due to Earth's gravity.



Newton is said to have discovered the law of gravity when he was hit by a falling apple. But Newton just watched the apple fall, wondering what force made it happen.

## Gravity affects everything, and everyone

English physicist Isaac Newton was the first to describe gravity. According to Newton's famous formula ( $F = GMm/r^2$ ), all objects with mass affect each other. Earth's orbit around the Sun is explained by the Sun's mass ( $M$ ) pulling at Earth's mass ( $m$ ), keeping the planet at a specific distance ( $r$ ). However, Newton's formula could not explain, why the angle

of the planet Mercury's elliptic orbit relative to the Sun changes for every orbit made. The answer was given in 1916, when Albert Einstein introduced his relativity theory, stating that gravity bends space. Mercury is kept in its orbit because the Sun's powerful gravitational field produces a bowl-shaped bend of space, through which the planet "rolls".

*Gravity is calculated according to this formula:*

$$F = G \times M \times m / r^2$$

*The Sun's mass*

*gravity*

*the distance between the Sun and Earth*

*Earth's mass*

Newton's law of gravity includes a very small gravitational constant – an empirical physical constant that applies throughout the universe. It indicates the gravity between two 1 kg objects 1 m apart. The formula for the constant shows that the gravity between the two is rather weak:

$$6.67384 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$$



**Did you know:** just four forces of nature govern the universe? The electromagnetic force and gravity have infinite reach (as far as we know).

# Gravity force

Electromagnetic  
Strong nuclear  
Weak nuclear



## Gravity reveals that the Greenland ice sheet is melting

The two GRACE satellites have measured variations in Earth's gravitational field since their launch in 2002. Today, we know that the Greenland ice sheet is melting, because the satellites have detected a loss of mass in Greenland.

1

The GRACE satellites orbit Earth at a distance of **220 km**, as they are constantly affected by Earth's gravitational field. Solid land masses pull more at the satellites than oceans do.

2

When the satellites pass over Greenland, **the mass of the ice** first pulls at one satellite and subsequently at the second one, producing slight variations of the distance between the two, measured by means of microwaves.

3

The changes in distance are calculated into the local gravitational field and into **ice sheet mass** variation. So, repeated fly-overs have revealed that the ice is melting.

The Greenland ice sheet pulls at one GRACE satellite.

Microwaves pass between the satellites.

The second GRACE satellite registers the changing distance to its twin. The bigger the variation, the bigger the ice mass.

## No diets on Jupiter

On Jupiter, the standard gravity is 2.5 times that on Earth. A person who weighs 90 kg on Earth, weighs 212.7 kg "on" the gas giant.

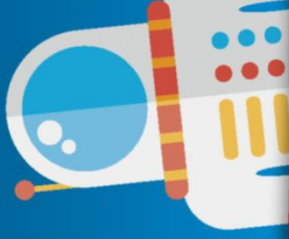
90 kg on Earth

212.7 kg on Jupiter





Astronauts experience weightlessness at the International Space Station (ISS). That is not due to gravity being absent, it is because the station is in a constant free fall in its orbit.



## Test your (new) knowledge

1. Why do you only "weigh" 16.6 % of normal on the Moon?
2. Are ISS astronauts weightless, because Earth's gravity does not reach that far into space?
3. According to (relativity) theory, how does the Sun keep Earth in its orbit?



ANSWER 1: The Moon's mass is only 16.6 % of Earth's mass. 2: No, the space station is in a constant free fall, making the astronauts weightless. 3: The Sun's gravitational field causes a bend of space, in which Earth is rolling.

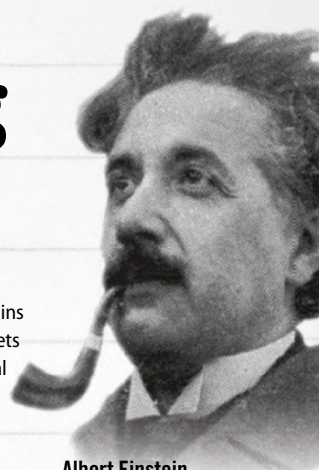
# From windfall apples to the Big Bang

## 1687

**Isaac Newton** provides the human race with a basic understanding of gravity when he publishes his book *Principia*. According to Newton's law of gravity, the mass of an object determines its force of attraction. The bigger the mass, the bigger the attraction. These descriptions are so accurate that they remain unchallenged for 229 years.

## >> 1916

**Albert Einstein** publishes his general relativity theory, which explains the Sun's gravitational effect on planets by the fact that the Sun's gravitational field produces a bowl-shaped bend of space, in which the planets roll.



Albert Einstein

## 1961

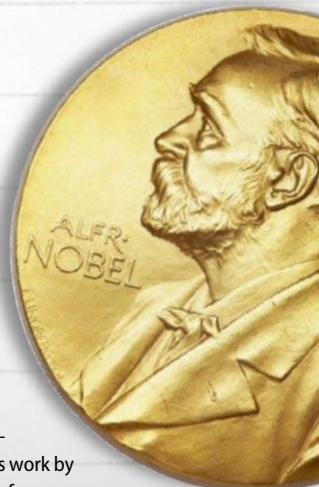
Russian cosmonaut **Yuri Gagarin** orbits Earth aboard the Vostok 1 spacecraft. He is the first man to orbit so fast around Earth that he becomes weightless.



Yuri Gagarin

## >> 1983

Russell Hulse and Joseph Taylor are awarded the Nobel Prize for observations which indirectly prove the existence of **gravitational waves**, made by mass accelerating in supernovae etc.



## 2002

LIGO detectors in the US begin the search for gravitational waves. **The detectors** consist of two 4-km-long tunnels with mirrors at the ends. If a gravitational wave hits the detector, the mirrors of one tunnel are squeezed together, whereas the mirrors of the other are pushed apart. The ultra-tiny motions are detected by means of laser beams.

## >> 2012

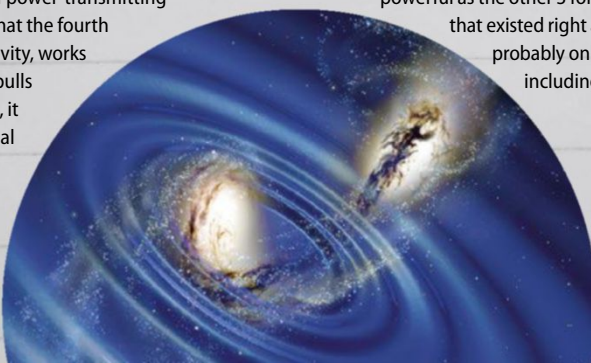
**Physicists detect the Higgs boson**, establishing that the electro-magnetic force and the nuclear forces work by emitting and receiving small parcels of energy known as quanta. According to theorists, gravity is transmitted between masses in the same way.

# 2015 Particles transmit gravity

**E**xperiments have shown that 3 of 4 fundamental forces of nature, the electromagnetic force and the strong and weak nuclear forces, work by means of power-transmitting particles. So, physicists believe that the fourth fundamental force of nature, gravity, works in the same way. When the Sun pulls at Earth, according to the theory, it happens by emitting gravitational particles known as gravitons. The theory will be difficult to prove, as gravity is weak

compared to the other forces. Even a small magnet will easily overcome Earth's gravity, lifting a needle from the ground. Gravity is only as powerful as the other 3 forces of nature at the extreme energies that existed right after the Big Bang. So, gravitons can probably only be produced in experiments including the same amounts of energy.

According to the most recent theory, gravity works by the exchange of gravitational particles: gravitons.





# TWINS SOL GENE MYST

Identical twins such as Mark and Scott Kelly can shed light on the effect of long space voyages, etc. on the human body.

ROBERT MARKOWITZ/NASA

**MARK KELLY**






# WE FRIES



**SCOTT KELLY**

Identical twins are the perfect test subjects, as genetically speaking, they are almost the same. This allows scientists to answer the question of what means the most, nature or nurture? Are happiness and personality genetic, or are they influenced by nurture? Their near-identical bodies also provide a unique opportunity to study the effect of extremes such as space missions that go on for several years.

By Rasmus Thirup Beck



The only identical **astronaut twins** will reveal the effect of weightlessness on the human body – one from Earth, the other from the International Space Station (ISS).



SHUTTERSTOCK



# IDENTICAL TWINS ARE 0.5% DIFFERENT

Identical twins develop based on the same genetic material and are consequently very much alike – but up to 0.5% of their genes may vary from one to the other.

Twins who grow from the same fertilized egg – so-called identical twins – are basically genetically identical, because they develop from the genetic material of one egg and one sperm cell. But shortly after the egg divides in two, the babies begin to develop differences. For example, the amniotic fluid of the womb shapes the lines of the two babies' hands and fingers, so they do not have the same fingerprints. The differences grow even more marked after birth, when so-called epigenetics comes into play. Our genetic profile is changed slightly by the environment that we live in and the things we experience. That is also true for identical twins who ought to become equally tall – but if one twin does not get as much nourishment as the other, pronounced differences may occur.

In spite of different effects, only 0.5 % of identical twins' genes can develop in different directions after their conception.

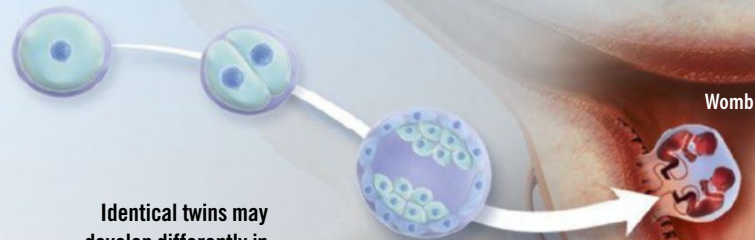
## Egg division produces two identical people

**1** An egg leaves the ovary and is fertilised by a sperm cell in the woman's oviduct.

**2** A maximum of 13 days later, the egg spontaneously divides in two inside the womb.

**3** The egg develops into two babies with the very same genes. Their eyes and hair will be of the same colour.

**4** In spite of the identical genes, the babies turn out slightly different. The amniotic fluid affects the twins' fingers differently, so they develop non-identical fingerprints.



Identical twins may develop differently in the womb, absorbing different amounts of nutrients and antibodies

CLAUS LUNAU / SHUTTERSTOCK



Although identical twins look the same, 0.5% of their genes may be different.

Identical twins are not 100 % alike – for instance, their **fingerprints are different.**



# 40%

of all twins develop their own common **language**, that nobody else can understand.



**T**he 73 million twins in the world are a scientific gold mine for human biologists, psychologists and more. Twin studies allow us to try to find out if a person's qualities are due to nature, or genetics, and if they are more affected by nurture, or environmental factors. Identical twins even allow us to look very accurately into the human body's reaction to specific effects – since genetically, identical twins are a minimum of 99.5 % the same, one twin can participate in the experiment, while the other is the control subject.

That is exactly what will happen in the case of the world's only astronaut twins. Scott Kelly will spend the next year at the International Space Station (ISS) while his twin, Mark Kelly, remains on the ground. During the experiment, they will be carefully monitored by scientists to find out how the human body reacts to a long period in space involving a high radiation level and extended periods spent in free-fall.

## ASTRONAUTS LOSE MUSCLE MASS

Humans are specifically adapted to life on Earth, where gravity pulls the body down. Gravity maintains body muscles, as it requires force to move about, and it sees to it that the bodily fluids – blood and water – are correctly distributed. In a state of weightlessness, there is no force to keep the body in place, so astronauts lose muscle and bone mass and retain fluid in their chests and heads. But the visible effects are not the only changes that the human body is subjected to during a long visit to space. Before, during, and after Scott's stay in space, the Kelly brothers will be subjected to a number of tests concerning mucosa, urine, blood, saliva, and faeces, in order for scientists to study their DNA and check the functions of the body's transport agents such as proteins. Their muscle mass,

stamina, and the distribution of liquid will also be registered.

The tests will be analysed by NASA's Human Exploration Research Opportunities (HERO). Scientists from 10 different projects will study, whether Scott's immune system and genes change during the long space mission.

Professor Susan Bailey of the Colorado State University will take a look at the twins' telomeres – the small sequences at the ends of chromosomes, which become shorter, every time a cell divides. The telomeres provide a rough idea of a human being's biological age, but they also become shorter under the effect of stress, so scientists expect that Scott's telomeres will be shortened faster in space than Mark's will on Earth.

The material for the study that Fred Turek from the Northwestern University is to make will come from the space station's toilet. He plans to analyse the bacteria that live inside us. The intestinal flora means a lot to the way, in which the body combats diseases, and scientists know very little about how the intestinal flora reacts in space.



MARK SOWAN/NASA

**“After spending one year at the ISS, Scott Kelly's genes can reveal the effect of space on his body.”**

## Twins were used in experiments

In 1979, a special research project was initiated in Minnesota, USA. Immediately after birth, identical twins were given up for adoption by different families. The aim was to study the development of separated twins. One good example are the Jim Twins, who met for the first time at the age of 39. Several striking similarities could be observed: They have the same name, divorced a woman named Linda, married one named Betty, and once had a dog named Toy.

Their sons are James Allan and James Alan.



**Though separated, the Jim Twins developed very similarly.**

NANCY L. SEGAL

The aim of the new research project is to prepare NASA for the next stage of the space adventure: space missions that last several years – such as a manned mission to Mars, that would take approximately three years.

## HAPPINESS IS GENETIC

NASA is not the only party interested in twin research. Scientific departments of universities around the world have dedicated themselves to studying the almost identical pairs to find out whether nature or nurture influences human development the most.

Scientists from one of the world's most well-known twin research institutes, the Minnesota Centre for Twin and Family Research, have studied whether happiness is determined by the genes. The scientists analysed the degree of happiness of 1,300 identical and non-identical twins via

Identical twins are always of the **same sex**, as they originate from one single egg with the same sex chromosomes.



China has the **lowest** rate of twin deliveries – 1 in 300 deliveries.



# Nazi doctor aimed to find the key to twin deliveries

Twins were popular in concentration camps. Doctors tried to learn how to produce twin pregnancies to make the Aryan race grow fast.

The notorious German doctor Josef Mengele carried out terrible medical experiments on prisoners of the Auschwitz concentration camp, taking a special interest in twins. He hoped to find a way to boost twin pregnancies, so the Aryan race could grow faster and become dominant. A total of 3,000 twins were taken to the camp's ward for human experiments. Mengele was not sure where to look for the key to twin conception, and so, he drew their blood, removed organs and limbs, and infected them with deadly diseases – always with

one twin as the control subject. In 2009, Argentinian historian Jorge Camarasa claimed that Mengele is responsible for an extraordinary rate of twins in the Brazilian city of Cândido Godói – blond, blue-eyed twins, by the way. Josef Mengele visited the area and reportedly treated the women of the city. Subsequently, about one in five pregnancies resulted in twin deliveries. However, according to geneticists, the phenomenon is due to inbreeding, as the area is very remote.



Josef Mengele was an SS officer and doctor in the Auschwitz death camp during World War II.

▶ questionnaires and found out that social status, educational level, income, marital status, and religion meant very little to the perceived well-being of the test subjects. Half of the happiness was ascribed to the genes, as the twins were equally happy – most characteristically among identical twins – and the degree of happiness varied between twin pairs. When the scientists repeated the study 10 years later, they discovered that, unlike what they expected, nurture was less important to the degree of happiness, the more years had passed. Now, some 80% of the twins' happiness was determined by genetics.

The idea that humans have our own free will has also been tested by scientists via twin research. As the vast majority of twins have grown up in the same home, scientists could assume that the twins in the experiment had the same upbringing as regards religion, morals, and social factors

– and had heard their parents discuss the same political beliefs over dinner. The scientists asked the twins a series of opinion-based questions about political stance, etc. and compared the replies of identical twins, who are almost genetically the same, with the replies of non-identical twins, who only share about half their DNA.

The identical twins' answers were markedly more alike, and so, the scientists

concluded that opinions are very much determined by nature – more than half of the twins' political opinions could be explained by their genetic profile.

An aspect, regarding which scientists have long known nurture to be very important, is life expectancy. An unhealthy lifestyle including fat food, stress, and pollution affects heart, lungs, and blood vessels negatively, but it also changes the genetic profile by for instance activating or deactivating genes that are responsible for different age-related diseases. In order to find out which genetic changes are caused by an unhealthy lifestyle, a team of scientists from King's College in London compared the genes of 172 identical twins aged 32-80. The scientists discovered 490 genetic changes in the twins, and by comparing those to the occurrence of age-related diseases, they found four genes that are directly related to cholesterol level,



The world's biggest twin festival is held every year in Ohio, USA.

Worldwide, there are around

**73** million pairs of twins.



Among **polar bears**, twins are not rare – twin deliveries are the most common.



lung function, and menopause. By testing people for the four genes, the diseases can be prevented.

### REGISTERS COLLECT TWIN DATA

Since English anthropologist Francis Galton carried out the first classic twin research in 1875, many different research projects have focused on twins, and in 2013, the number of scientific articles including the word "twins" exceeded 50,000.

The great interest in twin research is indicated by the fact that many countries have established a special twin register.

The very first one was set up in Denmark in 1954 and now contains information about 88,000 twin pairs born since 1870. Today, only the Swedish twin register is bigger.

The American Minnesota Twin Registry is one of the most successful, though it contains fewer data.

Since 1983, it has enabled groundbreaking research, such as the "Twins Reared

Apart" study about the development of identical twins who grow up apart.

The biggest register is the EU's, which includes data about 1.6 million European twins. Through new research projects, they may contribute to the ongoing discussion about whether nature or nurture is more important for human development, or they could reveal how extreme conditions such as space missions or new medication affect the human body. What's clear is that twins remain a key part of human science. 

## SAME GENES - DIFFERENT SKIN COLOUR

Although identical twins have the same parents and develop based on the same genes, the result can be very different. In extremely rare cases, the parents' genes are expressed so dissimilarly in the children that they get different skin colour.



One in a million. That is the likelihood of twins with the same parents being born with different skin colour.

NNP/EPA/SCANPIX



SAME MUM AND DAD



### Mirror image twins

are identical twins with reverse asymmetric features.

**Nigeria** boasts the highest rate of twin deliveries.



Identical twins occur, when a fertilised egg divides spontaneously – scientists **do not know why.**



The Return of the Airship:

# ZEPPELIN

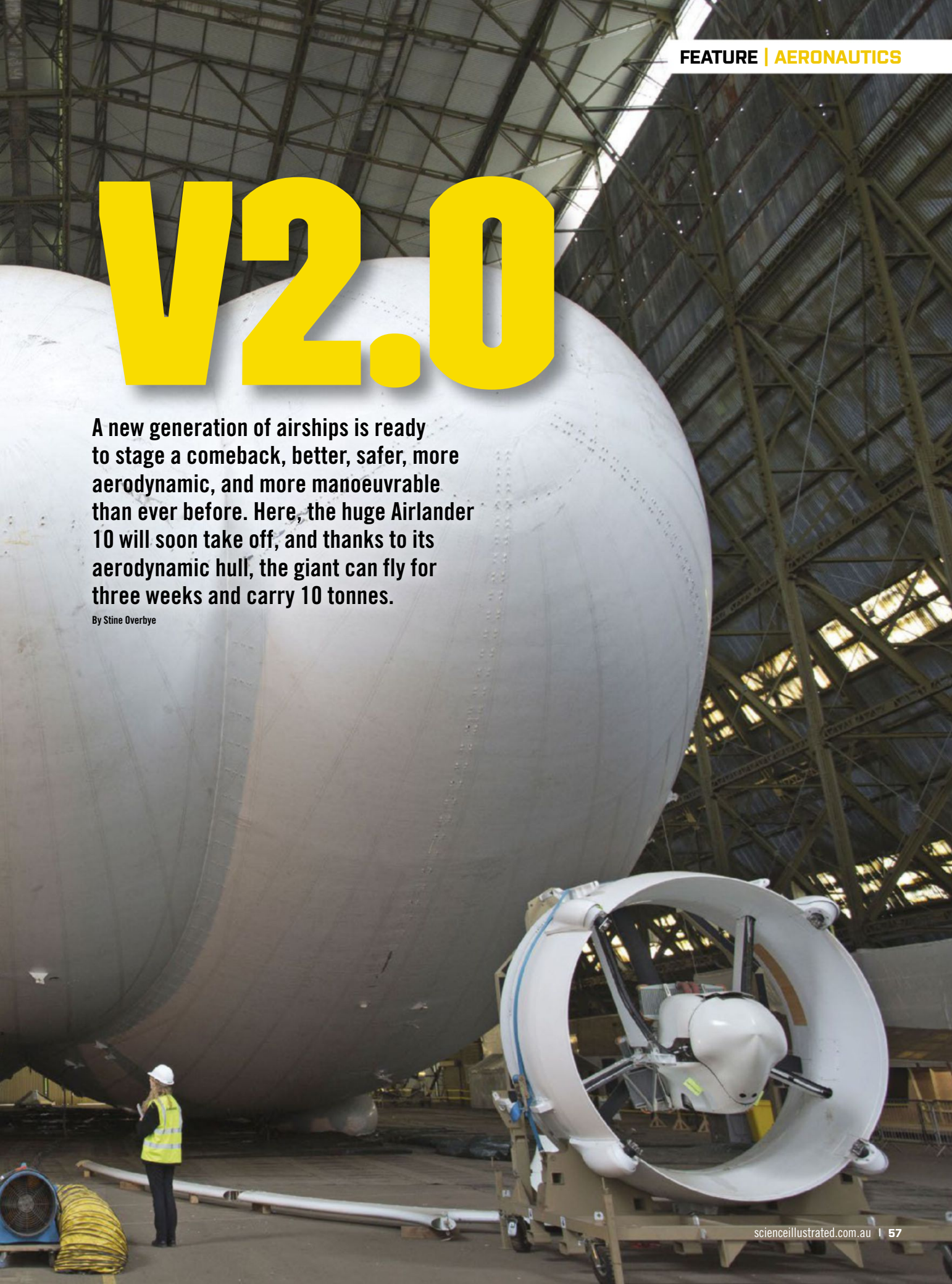
ALAMY/INARSELECT  
The Airlander is built in England in a huge hangar, which is 247 m long, 55 m wide, and 48 m high.



# V2.0

A new generation of airships is ready to stage a comeback, better, safer, more aerodynamic, and more manoeuvrable than ever before. Here, the huge Airlander 10 will soon take off, and thanks to its aerodynamic hull, the giant can fly for three weeks and carry 10 tonnes.

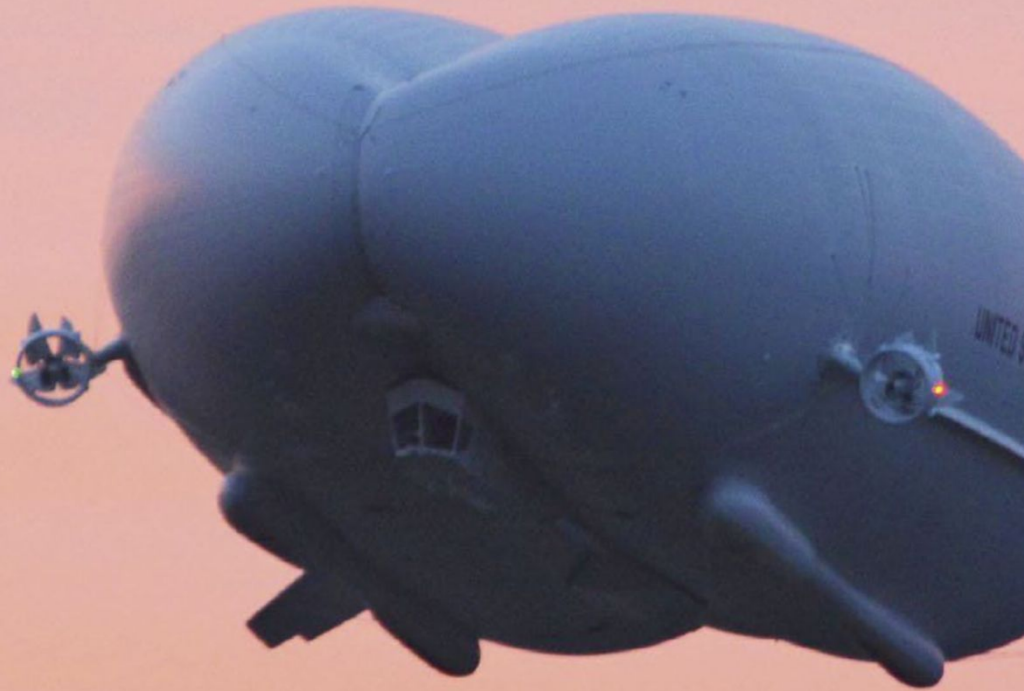
By Stine Overbye





HYBRID AIR VEHICLE

In August 2012, an Airlander prototype took off from the Naval Air Engineering Station Lakehurst in New Jersey, USA. The test flight lasted 1.5 hours.



## Past vs Future

The Airlander is a hybrid between a helicopter, an airship, and an aeroplane – a design that makes it more manoeuvrable than traditional airships.



### TRADITIONAL AIRSHIP

#### CONTROL:

Airships float but do not produce lift through aerodynamics. So, they are difficult to control in high wind or at hot/cold temperature extremes.

#### LIFTING POWER:

The balloon must be huge to lift cargo, as the lifting gas is the only thing producing lift.

#### LANDING:

Traditional airships are lighter than air and must be fastened to the ground or a mast when landing.



### HYBRID AIRSHIP

A hybrid's aerodynamic hull and powerful engines produce lift, make the ship manoeuvrable, and ensure a stable direction of flight.

Like an aeroplane, the ship uses the motion of the air across the hull – increasing lifting power.

On the ground, the Airlander weighs about the same as air. The engines can 'suction' onto the ground.





In an old hangar in the village of Cardington north of London, you will find a high-tech vehicle nicknamed “the flying bum”. It is neither a plane, nor a helicopter or a traditional airship. This unique means of transport can take off and land anywhere, fly for weeks, and lift tonnes of cargo.

The vehicle most of all looks like a huge, chubby plane filled with air, and measuring 92 m, it is 20 metres longer than a jumbo jet and 8 m longer than the world’s biggest plane, the Antonov An-225. Named Airlander 10, it is the longest aircraft in the world, but in only three years, it will be outmatched by its big brother, Airlander 50, which measures 119 m. The giant is the first in a fleet of similar airships, which are designed by several large aviation companies these days. According to plan, the Airlander 10 will conquer the sky in the summer of 2015 – marking the comeback of the great airships.

### DEVELOPED FOR WAR

Originally, the Airlander was developed for the US army, which in 2009 hired the British company Hybrid Air Vehicles, HAV, to design an airship for surveillance operations in war zones such as Afghanistan. The army wanted the airship to be remote-controlled and able to remain in the air for three weeks at a time: an all-seeing eye of the US forces. A prototype took off in August 2012 from the Naval Air Engineering Station Lakehurst

in New Jersey, USA. The test flight went strictly by the book, but shortly after, the army had to cut expenses, and the airship program was abandoned. HAV bought it back and is now refining it in Cardington.

### AIR DETERMINES FLIGHT ALTITUDE

Hybrid airships are the next generation of the old, giant airships that flew around the world 80 years ago. The vehicle is lifted by helium and by its aerodynamic hull. The giants of the past were lifted only by the gases in the “gas

bag”, but did not get any help from the shape of the envelope. The pilot was also forced to bring lots of ballast such as water or sand, which was simply dumped out the side,

when he wanted the ship to fly higher.

Airlander pilots need no ballast. Instead, they regulate flight altitude by compressing the lifting gas of helium. Apart from helium, the smooth hull includes air cells, and the more air the pilot pumps in, the heavier the vehicle gets. If the air cells are fully filled, the Airlander weighs about the same as air.

In order to prevent the airship from drifting off, HAV has designed the engines to provide downward suction. The Airlander has four engines, but one activated engine is sufficient to make it move forward. If all four engines were to unexpectedly fail, the airship would just descend slowly to the ground, as even without engine power, the Airlander ▶

**“ The Airlander 50 can fly 3,500 km on one tank of fuel, such as from Stockholm, Sweden, to Egypt for the passengers to admire the pyramids at close range.**



PHOTO: ALAMY/IMAGESELECT

The hangars in which the Airlander is built were erected 100 years ago for the huge R100 and R101 airships that once carried rich passengers around the world.



# This giant is a hybrid

The Airlander has borrowed the best features of a helicopter, a plane, and a traditional airship. Its movable engines make the vehicle take off like a peaceful, quiet helicopter, and a new landing system ensures soft landings anywhere.

## THE BOW THRUSTER

stabilises the airship and is used for sideways manoeuvring, particularly during landing.

## THE HULL

is double like a catamaran and functions like a chubby aeroplane. The pointed nose makes air pass over and under the hull and generate lift.

## TWO FORWARD PROPULSORS

allow the Airlander to quickly move up, down, and sideways.

## TWO AIR CUSHIONS

are located on each side of the gondola. During flight, the cushions are deflated, and the landing system is folded up.

## THE GONDOLA

or flight deck under the hull includes a control room seating two pilots.

## THE FREIGHT MODULE

of the Airlander 10 can hold three 20-foot containers or be converted into a passenger cabin.



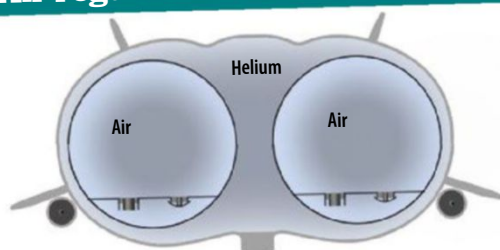
ALAMY/IMAGESELECT

## Air regulates lift

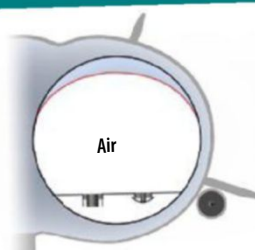
Sea level

Altitude: 3 km

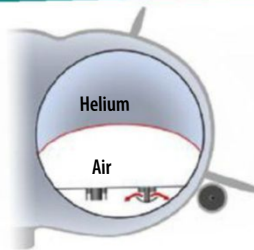
Altitude: 6 km



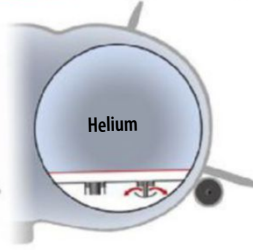
The pilots control lift by compressing helium with air in cells. When air is pumped in, the ship becomes heavier, and the lifting power of the helium is reduced, as the density increases.



**1.** On the ground, the air cells are filled, so the air ship is heavier than air.



**2.** The more air the pilot lets out via valves, the more lift is generated.



**3.** When all air has been let out, the helium has reached its maximum lifting power.



#### THE GAS BAG

is made of three thin layers of strong, flexible, and light fibre materials: Kevlar, Vectran, and Mylar. The balloon bag is optimised to retain helium, and is bulletproof and flexible.

#### HELIUM

is seven times lighter than atmospheric air and can lift 1,056 kg per m<sup>3</sup> of gas. The excellent lifting power makes helium an ideal lifting gas. Apart from helium cells, the balloon contains air space, allowing the internal pressure to be regulated, so the balloon is always fully inflated.

#### THE TAIL FIN

provides aeroplane-style directional stability.



#### FOUR DIESEL ENGINES

power the vehicle: two on the sides in the fore and two aft. The four V8 turbocharged diesel engines output 1,000 kW. The Airlander 50 will output no less than 7,450 kW.

#### MINIATURE WINGS

on both sides end in a fin. The design reduces disruptive turbulence and provides more lift

**“The Airlander’s state-of-the-art air cushion landing system allows the vehicle to land in deserted and hard-to-reach regions without airports or landing strips.”**

► gets 60 % of its lift from helium and is only slightly heavier than the air.

#### AIRSHIPS CAN LAND ANYWHERE

Like a helicopter, the vehicle is highly manoeuvrable and can take off and land vertically and virtually be parked in the air. The airship needs no runway, it can land on any level surface such as ice, snow, water, or sand. This is due to a new landing system consisting of air cushions, that make the airship ideal for carrying emergency aid to disaster areas and hard-to-reach regions without airports, roads, or other infrastructure.

Many old-fashioned airships landed on wheels and so were unable to land in deserted regions. Moreover, the engines were mounted on the gondola below the ship and could be torn off during landing, if the surface was not completely even.

The Airlander’s engines are located on the sides and the stern, so there is no risk that they will be damaged by landing. The airship is ideal for carrying spare parts and equipment to oil rigs, mines, or scientific bases in Antarctica. If the surface is too uneven, the Airlander can be “moored” a few metres above the ground.

#### SILENT SAFARI IN THE AIR

The hybrid airship can be used for border-crossing surveillance, search operations, bushfire fighting, communication centre purposes, and as an almost silent tool for scientists. From this technological perch, they can observe the fauna below.

But HAV also intends to use the Airlander for passenger transport. The giant flies at a maximum speed of some 150 km/h and so cannot compete with the 800–1,000 km/h of jet aeroplanes. But its low-noise engines and ability to fly at low altitudes make the airship ideal for sightseeing and safaris on the savannah or in the jungle. The ►

#### 2015: AIRLANDER 10

**LENGTH:** 92 m  
**WIDTH:** 43.5 m  
**HEIGHT:** 26 m  
**VOLUME:** 38,500 m<sup>3</sup>  
**TOP SPEED:** 148 km/h  
**MAXIMUM ALTITUDE:** 6,100 m  
**CARGO CAPACITY:** 10 tonnes or up to 50 passengers.  
**REACH:** 2,500 km on one tank of fuel. Can remain in the air for up to three weeks at a time, either crewed or remote-controlled. Test flights are scheduled to begin in the winter of 2015.

#### 2018: AIRLANDER 50

**LENGTH:** 119 m  
**WIDTH:** 60 m  
**HEIGHT:** 35 m  
**VOLUME:** 103,000 m<sup>3</sup>  
**TOP SPEED:** 195 km/h  
**MAXIMUM ALTITUDE:** 6,100 m  
**CARGO CAPACITY:** 70 t or up to around 400 passengers. The Airlander 50 features an integrated crane, which can lift 20 t at a time.  
**REACH:** Approximately 3,500 km on one tank of fuel. The maiden flight is planned for 2018, and wind tunnel tests should begin in late 2015.



# Heavy metal gets lighter than air

One of the key investors in the Airlander is 56-year-old Bruce Dickinson, the lead vocalist of the British heavy metal band Iron Maiden.

Bruce Dickinson is a trained pilot, and when Iron Maiden tours the world, he flies the band's customised Boeing 757, also known as Ed Force One. In between the tours, he is a flight instructor.

Dickinson's passion for aviation reaches far beyond jet airliners, and he has invested around \$600,000 in the Airlander project. According to him, airships can potentially

make aviation both greener and more fun, and he believes that the technology is now finally ripe for making airships an attractive and practical means of transport.

As a PR stunt, he plans a non-stop airship voyage going twice around the world in a few years, livestreaming the entire journey.

Until the dream comes true, Bruce Dickinson is a frequent guest in the hangar in Cardington, where the Airlander is being built, and where he observes the construction work closely.



Bruce Dickinson is the lead vocalist of Iron Maiden, which was formed in 1975 and has so far released 37 albums.

**“We intend to fly six metres above the Amazon River and pass by some of the biggest and most amazing cities in the world, streaming everything to the Internet.”**

Bruce Dickinson, Airlander investor and lead vocalist of the heavy metal band Iron Maiden.



## Cheapest form of air transport yet...

The cost of carrying 1 tonne of cargo 1 km:

CONTAINER VESSEL:	\$ 0.06
TRAIN:	\$ 0.11
TRUCK:	\$ 0.23
<b>AIRLANDER 50:</b>	<b>\$ 0.57</b>
TRUCK (ON GRAVEL ROADS AND ICE):	\$ 0.91
AIR FREIGHTER:	\$ 1.70
HELICOPTER:	\$ 3.40

GETTY IMAGES



► cargo compartment of the Airlander can also be turned into a luxury cabin - even with a swimming pool, restaurant, and cabins.

In addition, an Airlander flight will be a green alternative to planes. According to HAV, the airship consumes as little as 25 % of the fuel of an airliner.

## A GIANT FILLED WITH HARMLESS GAS

In the heyday of airships in the 1920s and 1930s, travellers enjoyed immense luxury en route. They were waited on hand and foot, and extravagant cabins were the very essence of travelling by airship.

But in the 1930s, this mode of travel suddenly lost its appeal after several accidents, which claimed numerous lives. The most famous one was the Hindenburg disaster, in which the huge German Hindenburg airship burst into an explosive fire during landing and crashed. The Hindenburg was full of extremely inflammable hydrogen, while the Airlander is lifted by helium, which

is less explosive. Helium is highly inactive and does not combine chemically with other materials. The gas can neither burn, nor explode, so the risk of repeating the Hindenburg disaster is non-existent. Unlike the dirigibles of the past, the Airlander hull is extremely durable and capable of resisting


**“ Today, only around 40 airships operate in the world, of which the majority are used for PR (like the Goodyear Blimp). But in 20 years, 1,000 airships could carry passengers and cargo.**

rupture. If the balloon were to catch fire, the Airlander will not crash like the Hindenburg. The cell structure inside the balloon makes sure that the vehicle will still have lift from its undamaged cells. The envelop is also bullet-proof and can resist the great pressure from the lifting gases.

## THE TIME OF THE GIANTS

According to HAV's calculations, the market for airships is promising, and 600-1,000 vehicles could conquer the sky in the next 20 years. Several companies are already designing hybrids like the Airlander, such as Worldwide Aeros in the US, RosAeroSystems in Russia, Solar Ship in Canada, and Varialift in the UK. Worldwide Aeros tested a small model of its airship, Aeroscraft, in September 2013, and RosAeroSystems' huge Atlant 30 will take off in 2017, featuring a massive lifting power of 30 tonnes.

Meanwhile, HAV is developing a giant which can lift 20 times as much as the Airlander 10. At this point in time, nobody knows when the Airlander 200 behemoth will take off, but according to the sketches, it will be able to carry 200 tonnes - corresponding to the weight of 2,500 grown men.

Airships mark a new age for flight. Forget stress, rushing, cramped conditions and tiny seats. Taking the slow route could mean it's all about the journey, not the destination. 

## RECORDS:

### 200 years of tradition up in smoke

In the beginning, airships were simple balloons, but they developed into a modern means of transport. The era ended due to accidents.

NATIONAL AIR AND SPACE MUSEUM, ARCHIVE, GETTY IMAGES, ALAMY/IMAGESELECT

#### BIGGEST: OH THE HUMANITY!

Measuring 245 m, the German airship **Hindenburg** was the biggest in the world. The vehicle was a flying luxury hotel, which began to take passengers across the Atlantic in 1936, from Germany to Brazil and the US. During a landing in the US on 6 May 1937, the vehicle burst into flames, and 37 seconds later, it crashed, killing 36 people.



#### MOST FATAL: 73 CASUALTIES

The most lethal airship disaster ever took place in the early morning of 4 April 1933, when the helium-filled **USS Akron** crashed in a severe storm off the coast of New Jersey, USA. 73 of 76 crew members and passengers were killed. The crash was due to the tail fin of the 239-m-long vehicle touching the water and being torn off.

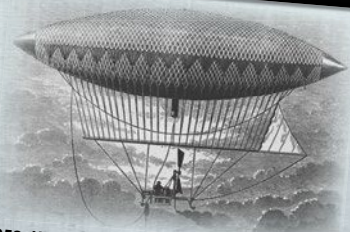


#### FIRST ROUND THE WORLD: 3 WEEKS

In 1929, the German **LZ 127 Graf Zeppelin** airship was the first to travel around the world - a feat that marked the peak of the Zeppelin era. Taking off from Lakehurst, New Jersey, USA, the airship continued round the world on an easterly course. The voyage lasted 21 days and 5.5 hours.



#### FIRST DIRIGIBLE: RUDDER



In 1852, Henri Giffard of France designed the first dirigible: a 42-m-long vehicle, including a cigar-shaped, hydrogen-filled balloon. To be able to control the ship, he installed a 3 HP steam engine and a rudder in the gondola. Giffard pointed the steam engine chimney away from the balloon to reduce the risk of fire.

#### FIRST CREW: 3 ANIMALS

A sheep, a duck, and a rooster made up the crew of the world's first "crewed" balloon voyage. The French brothers Joseph and Étienne Montgolfier were responsible for the hot-air balloon, which took off in 1783 from the Palace of Versailles near Paris.





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**MA/SCI36**



# ARTIFICIAL SPLEEN CAPTURES DISEASES

A ground-breaking invention might just **cure everything from food poisoning to HIV and Ebola:** It's an artificial spleen, capable of actually removing viruses and bacteria from the blood.

By Anders Enevold Grønlund. Art: Claus Lunau

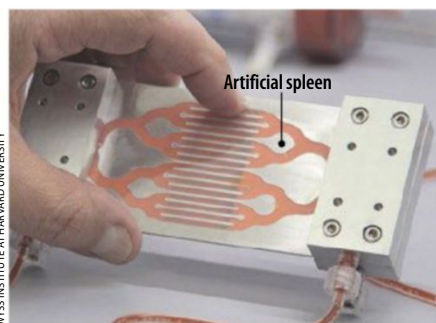
It sounds too good to be true: An artificial spleen linked to a patient's circulation. The blood leaves the body, passes through a device that removes viruses and bacteria, and healthy blood flows back into the patient's blood vessels. After a few hours, the blood has been purified, and the patient has recovered.

Scientists of the Harvard University in the US have developed an artificial spleen, which could become a universal weapon against disease. The potential is overwhelming. All bacteria and viruses that can attack or hide in the blood stream could be removed without the use of drugs or without even identifying the disease. Scientists expect the artificial spleen to be able to remove severe bacterial infections such as *E. coli* and staphylococci, cancer cells, and several types of virus – including killers like HIV, hepatitis, and Ebola.

## INSPIRED BY BLOOD POISONING

The artificial spleen idea emerged when scientists were looking for a new method to combat blood poisoning. Every year, as many as 18 million people are affected by the potentially fatal disease, which is caused by bacteria and fungi spreading in the bloodstream, causing inflammation. In more than half of the cases, it is impossible to diagnose the cause of the infection.

So, instead of targeting the drugs at certain bacteria and viruses, the scientists decided to explore the possibility of removing bacteria and viruses from the blood by filtration. The scientists were inspired by the spleen, which is responsible for removing worn out cells and alien organisms from the blood. The spleen works by forcing blood



Blood leaves the patient's body from an artery right before the natural spleen to be purified by the artificial spleen.

through an intricately branching network of tiny blood vessels lined with antibodies and macro-phages: the refuse collectors of the immune system, which purify the blood. With this in mind, the scientists set out to design an artificial spleen.

## BACTERIA REMOVED WITH A MAGNET

The result was a metal frame with canals, through which the blood is forced. The artificial spleen consists of two chambers. When the blood flows into one chamber, it is mixed with a protein known as MBL with magnetic nano-beads attached.

MBL is a natural protein that forms part of the immune system's anti-infection alert system. The special quality of MBL is that the protein will bind to almost anything invading the body. When MBL binds to disease organisms such as bacteria, the immune system knows that the bacteria must be destroyed. The MBL protein consists of a head and a long, sticky tail. The head sticks to certain sugar molecules on the surface of

all types of alien fungi, bacteria, viruses, parasites, and toxins, whereas the tail activates combat ready immune cells. Scientists have created a genetically modified version of MBL, in which the tail is replaced by a protein part, which can be attached to magnetic nanobeads. When the blood flows into the artificial spleen, the magnetic nanobeads immediately capture viruses and bacteria.

The artificial spleen's second chamber contains sterile salt water, which flows past a magnet. When viruses and bacteria from the blood have been captured and bound by the magnetic nanobeads, they are drawn to the second chamber by the magnetic field of the salt water via small canals. So, viruses and bacteria are removed from the blood flow, and the purified blood can be returned to the patient.

Scientists imagine that the artificial spleen will function according to the same principle as when kidney patients go through dialysis; a treatment which replaces the function of the kidneys. The artificial spleen will be linked to the patient's blood system right before the spleen: the blood flows out of the body (artery), through the artificial spleen and back into the patient's vein right after the spleen.

## SUCCESSFUL RAT EXPERIMENT

The artificial spleen has been tested on rats, with amazing results. The rats' blood was infected with the most common blood poisoning bacteria of humans: *E. coli* and *S. aureus* (Golden Staph). After five hours, the artificial spleen had removed 90% of the bacteria and their toxins. Even better, 90% of the rats survived, and the inflammation of



lungs and other organs had been markedly reduced. Only 14 % of the rats in the control, whose blood was not purified, survived.

### WORKS ON HUMAN BLOOD

The scientists observed the same effect, when they tested the artificial spleen on human blood. Five litres of blood from random donors were mixed with different types of disease-causing and antibiotic-resistant bacteria such


as E. coli and MRSA and directed through the artificial spleen. Also in

**“The scientists tested the device on rats. After five hours of filtration, the artificial spleen had removed 90% of the bacteria and their toxins.”**

this case, more than 90% of the bacteria were removed. Although this means that 10% of the bacteria still remain, scientists expect that antibiotics and the immune system will be able to combat the infection. In one hour, the artificial spleen can purify

0.5-1 litre of human blood. But several spleens working at the same time can probably do the job faster.

The method is revolutionary, because doctors don't need to kill the disease-causing organisms. It is sufficient to capture and remove them. So, it is no longer necessary to develop medication against every existing disease. And as the artificial spleen removes bacteria without the use of drugs, the invention can also reduce the use of antibiotics, benefitting the fight against antibiotics resistance.

The next step will be refining the technology, and subsequently, scientists will study its effect on Ebola and HIV. 

The device is linked to the patient's artery in front of the spleen. The blood flows out of the body, through the artificial spleen, and back to the patient.

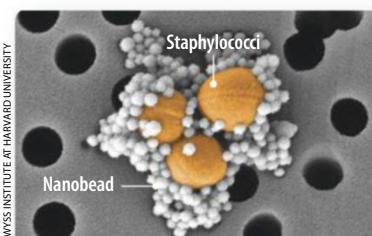
Spleen

## Magnet removes bacteria from blood

Magnetic nanobeads detect, capture, and stick to viruses and bacteria, which can subsequently be removed from the blood by a simple but powerful magnet.

Infected blood flows into the artificial spleen.

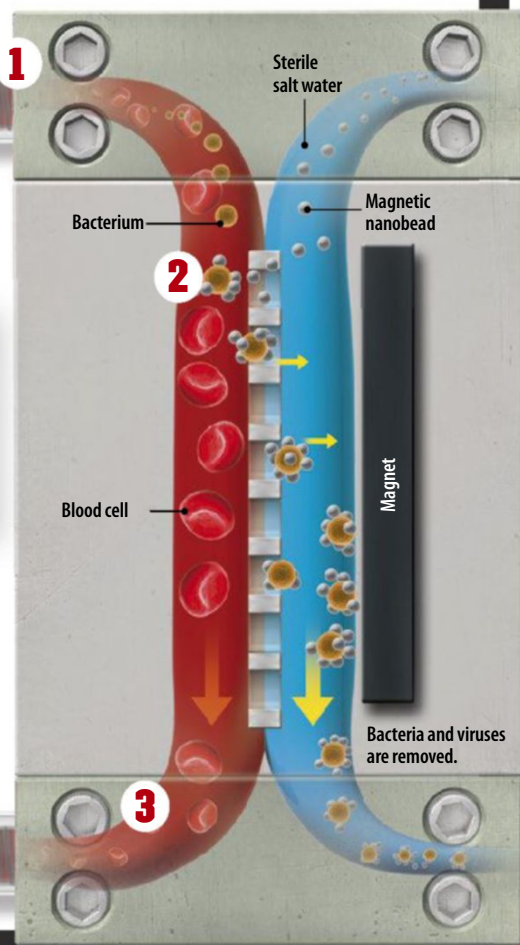
**1** The blood is pumped from the patient to the artificial spleen, which consists of a thin metal plate and lots of canals, through which the blood spreads.



**2** In the artificial spleen, the blood is mixed with magnetic nanobeads, which detect viruses and bacteria, binding to the disease organisms.

**3** A magnet draws the magnetic nanobeads with viruses and bacteria from the blood into a neutral liquid. The purified blood is returned to the patient.

Purified blood returns to the body.



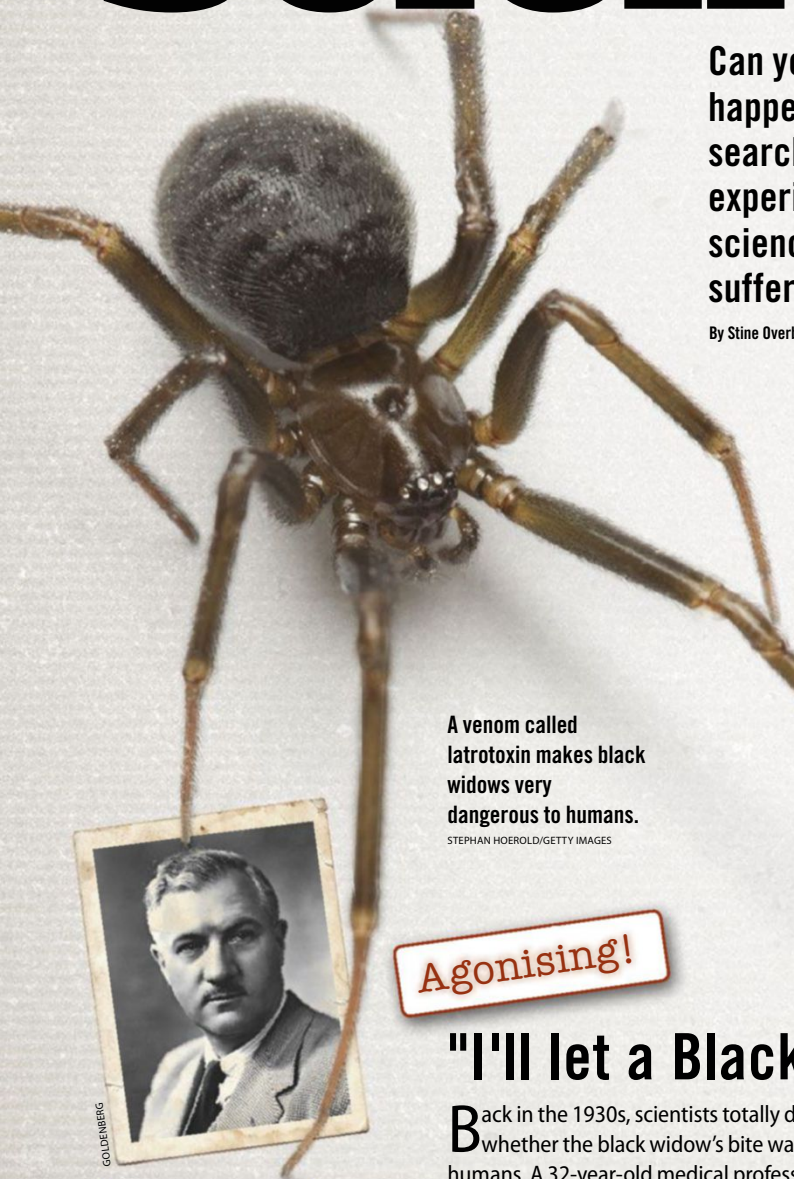


FROM THE  
SCIENTIFIC ARCHIVES

# Guinea-pig Scientists

Can you remove your own appendix? And what happens to the body when you get hanged? In search of answers, scientists have self-experimented over the years. In the name of science, they subjected themselves to all kinds of suffering – often risking their lives and health.

By Stine Overbye



A venom called latrotoxin makes black widows very dangerous to humans.

STEPHAN HOEROLD/GETTY IMAGES

Agonising!

Breathtaking!

"I'll hang myself repeatedly!"

In the early 1900s, Romanian forensic scientist Nicolae Minovici conducted a series of (nearly) break-neck experiments to learn more about how it felt to be hanged.

From lying on a bed and tightening a loop around his own neck, the experiments developed into him swinging 2 m above the ground in a loop.

Despite extreme pain, Nicolae Minovici persisted in his experimental efforts, which he finally

described in a 200-page paper. In short: it sucks.

**WHAT HE DISCOVERED**

He described what it was like to be hanged.

"I'll let a Black Widow bite me!"

Back in the 1930s, scientists totally disagreed about whether the black widow's bite was toxic to humans. A 32-year-old medical professor Allan Walker Blair decided to do take the matter into his own hands, allowing himself to be bitten by a female spider.

Blair's muscles cramped, he struggled to breathe, and writhed in agony, sweated profusely, and his blood pressure plummeted. The professor was hurried

to a hospital, and after several days of agony, a doctor said that he had never seen a patient suffer so much. After a week, Blair regained his health – but only after several morphine injections.

In the months following the bite, his entire body itched, and the skin of both hands and feet felt like it was on fire. Blair concluded that "the bite of a female black widow is indeed dangerously poisonous."

**WHAT HE DISCOVERED**

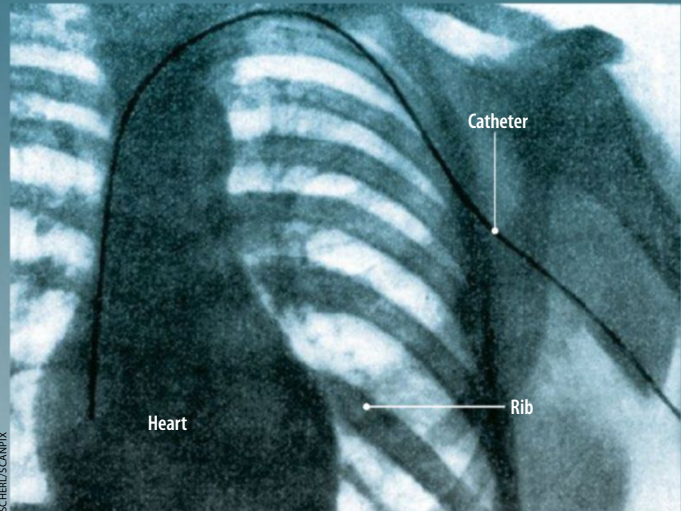
He convinced the many sceptics of his time that the bite of a black widow is potentially lethal for humans.



## Heartstopping!

## HEART MADE CATHETER MOVE

Werner Forssmann inserted a catheter into a vein at his elbow. Fluoroscopy allowed him to observe how the catheter moved with the blood towards his heart, and how the catheter ended up in the right ventricular cavity of his heart.



# "I'll stick a catheter into my heart!"

Today, this method is commonly used in heart surgery. But Werner Forssmann's heart catheter experiments went unrecognised for years. The technique was so extreme, most surgeons thought it too dangerous.

In the early days of heart surgery, doctors debated whether a patient could survive having his heart examined by a catheter that was inserted via an artery. Most of them thought that such a method would be lethal, but not Werner Forssmann: a 25-year-old German doctor who worked at a hospital in Eberswalde near Berlin.

One day in the summer of 1929, he decided to spend his lunch break experimenting on himself. He inserted a 65-cm, slim catheter into a blood vessel in his arm and pushed it into the right ventricle of

his heart. In the hospital's X-ray department, he observed the catheter move towards its goal and his great triumph: he had demonstrated that the method was possible, and even more importantly, he had survived it.

Shortly after, Forssmann published a paper about his experience without earning any credit at all. His colleagues denounced the method, which they considered too risky.

In the 1940s, Werner Forssmann finally managed to convince the medical community, and today, his method is widely used in cardiac surgical theatres throughout the world.

After World War II, Forssmann took up the study of the urinary tract and urology.

BETTMANN/CORBIS/ALL OVER

## WHAT HE DISCOVERED

**Forssmann's method allows pressure measuring in the heart. In 1956, he was awarded the Nobel Prize for inventing the technique.**

Minovici found it difficult to swallow for two months after his last hanging.

THE MINOVICI FOUNDATION





**Mindblowing!**



Stapp experienced the worst pain and the highest G force during the abrupt deceleration.

NASA/SPL/SCANPIX

#### WHAT HE DISCOVERED

Pilots can survive the effects of extreme g-force, as they eject from a supersonic aircraft.

## "I'll take a 1000 mph sled ride!"

Violent forces can injure or kill a pilot who ejects from a jet aircraft. John Stapp learned the hard way whether survival could be guaranteed.

The last thing John Stapp managed to say, before the Sonic Wind 1 rocket sled accelerated was:

"I assure you, I'm not looking forward to it."

Stapp was a doctor working for the US Air Force, and hoped to discover whether a fighter pilot could survive being catapulted out of a supersonic aircraft. And so, he volunteered to be the guinea-pig. Repeatedly, he let himself be strapped into a rocket sled moving on rails.

One day in December 1954, Stapp was about to initiate his 29th mission, the harshest so far, in which the nine rockets of

the sledge would accelerate him to over 1000 km/h. In previous experiments, Stapp had broken his tail bone and several ribs and suffered bleeding in his eyes, so he was well aware that he was risking his life.

And this time was no exception. The deceleration was so sudden that the blood vessels of Stapp's eyes burst, and his eyeballs shot forward in their sockets. The scientist lost his eyesight for a while, but on the other hand, he became the fastest man on Earth, and he had proved that fighter pilots can survive the forces of extreme acceleration and abrupt deceleration.



CORBIS/ALLOVER

Stapp was often so bruised that he needed help to get out of the sled.

## Sonic Wind 1 - the ultra-fast sledge

The sledge was powered by a varying number of rockets.

In the experiments, John Stapp was subjected to up to 46 G.

The sledge was decelerated by water between the rails. In one experiment, Stapp went from 1,017 km/h to 0 in 1.4 seconds.

SONIC WIND NO. 1

The sledge weighed 680 kg and gained a speed of 1,017 km/h in the fastest experiment.

The experiments were carried out on a 610 metre track.

ALLAN HOEN



**Eye-brow-raising!**

## "I'll remove my own appendix"

In February 1921, Evan O'Neill Kane, an experienced surgeon, decided to become his own patient. He intended to remove his own appendix and test whether local anaesthetic was sufficient for the surgery.

Leaning against pillows and assisted by a mirror, the 60-year-old man settled himself on the operating table, injected himself with anaesthetic, and cut his own abdomen open, exposing the muscle and appendix.

Half an hour later, the surgery had been completed. Kane no longer had an appendix, but he

had learned that the pain could be blocked by local anaesthetic.

Kane quickly recovered from the operation, and encouraged by the success, he carried out self-surgery once again 11 years later – this time to cure a groin hernia. The much more complex surgery lasted two hours, but was also successful.

### WHAT HE DISCOVERED

**It is possible to carry out surgery on a patient, who is conscious, and under local anaesthetic, which is less dangerous than full general.**

The nurses did not know how to behave as Evan O'Neill Kane performed surgery on himself.

CREATIVE COMMONS

## THEY ATE AND THEY DRANK

**Vomit inducing!**



Barry J. Marshall (left) and Robin Warren were awarded the Nobel Prize in 2005 for their findings.



### WHAT THEY DISCOVERED

**Their research paved the way for treating ulcers with a relatively simple antibiotics cure.**

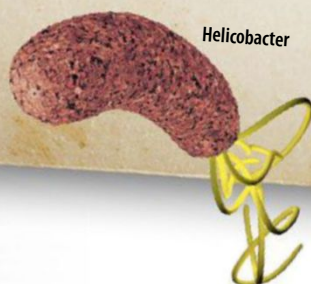
## "I'll drink infected chicken soup!"

In the early 1980s, a young Australian scientist, Barry J. Marshall, and his colleague Robin Warren decided to prove stomach ulcers are caused by the helicobacter bacterium, not by stress or strong coffee, as previously believed.

But when doctors and scientists throughout the world ridiculed the two, calling them quack doctors, Marshall used drastic means

to prove that he was right. He ingested a cup of helicobacter bacteria, which "tasted a bit like cold chicken soup".

An ulcer developed, teeming with bacteria. After curing the ulcer with antibiotics, the theory had been vindicated.



**Gut-busting!**

## "I'll only eat potatoes, cabbage and bread"

During World War II, Elsie Widdowson experimented with a diet of bread, potatoes, and cabbage, which despite other food shortages, were almost always available in England.

Elsie Widdowson was on the diet for three months. She lost a lot of weight, but in order to prove that the diet was sufficient, she went to the Lake District national park, where she burned 4,700 kcal in one day, hiking 58 km and climbing 2 km into the mountains.

Widdowson stood up to the challenge, and showed that the diet covered all her body's needs, except for calcium.



### WHAT SHE DISCOVERED

**Her research formed the basis of the British government's rationing policy during World War II.**

Widdowson also experimented with an intravenous intake of minerals and vitamins.





# *This concept sub hits speeds of* **5,000 km/h**

Chinese engineers claim they can develop a submarine that will hit speeds over 5,000 km/h. Such a vessel would be able to cross the Atlantic in just one hour, by taking advantage of supercavitation, where the sub produces its own air bubble and avoids the drag created by water, that would otherwise reduce its speed.

By Torben Simonsen

**FREAKY  
FUTURE!**



Air bubble produced by supercavitation

Submarine

Rocket engines

The submarine will move inside an air bubble, avoiding water drag.

MIKKEL JUUL JENSEN

## COULD THIS INCREDIBLE MACHINE CROSS THE ATLANTIC IN ONE HOUR?

If engineers actually build a sub that can move at the speed of sound in water (5,436 km/h) the distance from Lisbon to New York City can be covered in about one hour.

**1 hour**

**SUPERCAVITATION SUBMARINE**

New York

Lisbon

Atlantic Ocean

**73.5 hours**  
**THE WORLD'S FASTEST SUBMARINE** – the Russian Alfa class – crosses the Atlantic in about three days.

**7 hours**  
**AIRLINERS** normally complete a flight between Lisbon and New York City in approximately seven hours.

**98 hours**  
**THE QUEEN MARY 2**, one of the world's fastest cruise ships, travels across the Atlantic in four days (doing 30 knots).



**A** glittering vessel is moored to the quay, ready for departure. A narrow gangway leads to a small hatch, which is barely big enough for an adult to pass through. Excited crew members are getting ready for a test voyage. They put on pressure suits with breathing equipment. Their luggage is stowed into a pressure-sealed container and placed in a separate room. It is not possible for the men to stand upright, so they move about the submarine in a hunched position. Soon, they will be the first humans to race through the ocean at speeds close to that of sound in water – around 5,436 km/h.

This scenario could come true in the near future. Speeds of 5,000+ km/h through ocean water are theoretically possible, and a team of Chinese engineers have made a crucial breakthrough, which could make the

dream come true over time. At this point, only a few sketches exist of how the technology will function, but the principle is well-known, as it is already used in torpedoes. The secret is supercavitation, by which a vessel moves through the ocean inside a self-generated air bubble, avoiding the effect of water drag.

### **WATER DRAG SLOWS SUBS DOWN**

Conventional submarines cannot break speed records comparable to those of ships moving at the surface of the ocean. In spite of nuclear reactors and a streamlined

**“In spite of nuclear reactors and a streamlined design similar to a blue whale, even the most sophisticated existing subs move no faster than 80 km/h.**

design resembling the shape of a blue whale, even the most sophisticated subs move at speeds of no more than 60-80 km/h. The water drag makes it

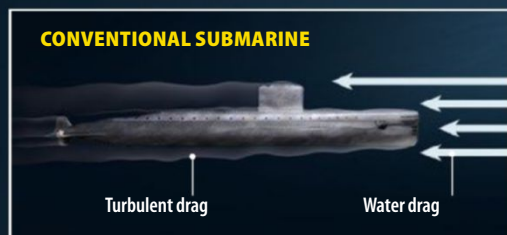
impossible to go any faster equipped with the technology used by engineers today. This is due to the fact that subs are entirely submerged in water, and drag affects the entire hull. A ship moving at the surface is only partly affected by water drag. Water is about 800 times as dense as air, so the water drag is some 800 times that of the air affecting a car. Moreover, the faster a conventional submarine moves, the greater the drag, as the increased speed will

# AIR BUBBLE DEFEATS DRAG

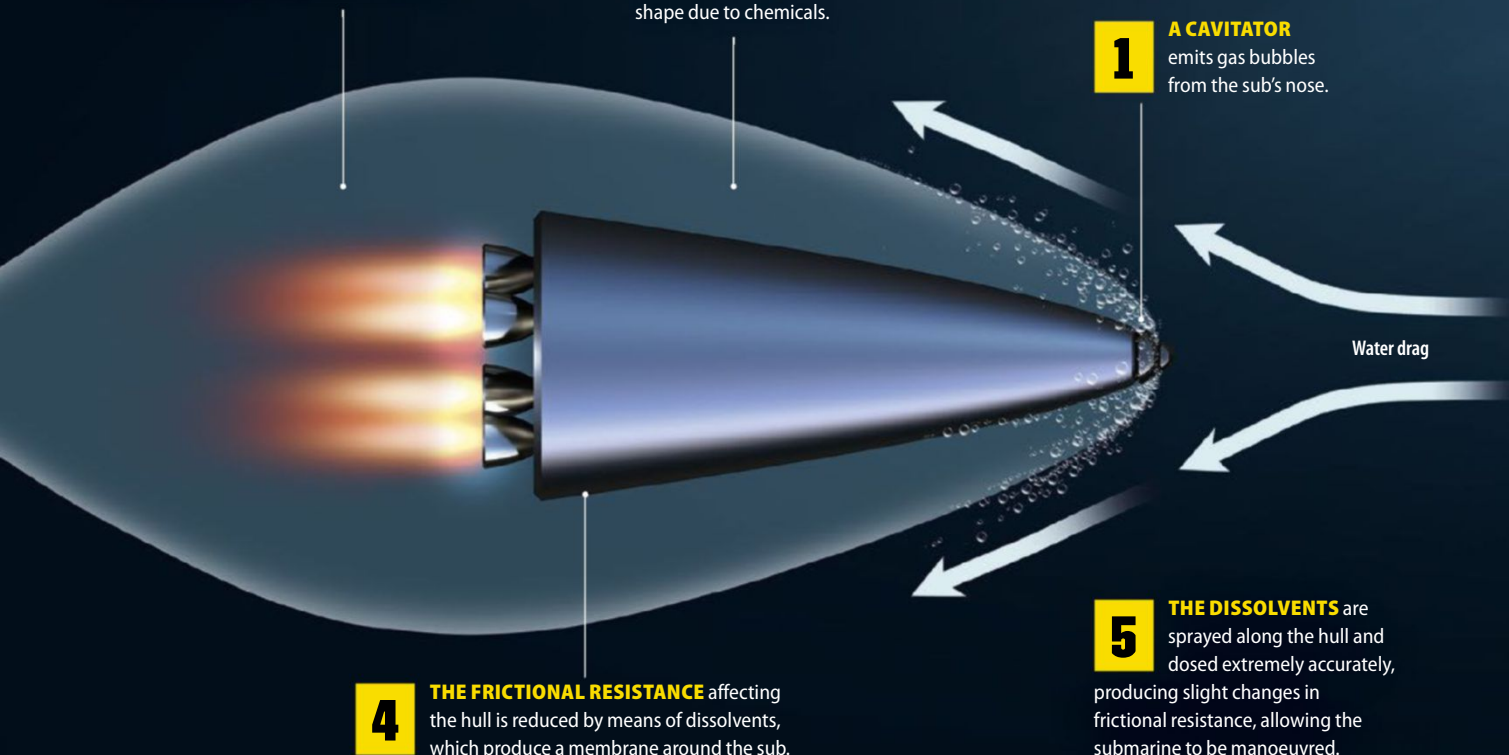
The secret of supercavitation is that the submarine moves inside an air bubble, so only its bow is in direct contact with the water. Consequently, the water drag, which normally prevents subs from sailing very fast, is reduced.

**3 THE SUBMARINE** is no longer in direct contact with the water. When the sub moves inside the air bubble, it avoids drag, allowing the vessel to move extremely fast.

**2 THE GAS BUBBLES** unite, surrounding the sub. The air bubbles maintain their shape due to chemicals.



**1 A CAVITATOR** emits gas bubbles from the sub's nose.



**4 THE FRICTIONAL RESISTANCE** affecting the hull is reduced by means of dissolvents, which produce a membrane around the sub.

**5 THE DISSOLVENTS** are sprayed along the hull and dosed extremely accurately, producing slight changes in frictional resistance, allowing the submarine to be manoeuvred.



enhance frictional resistance. As a result, even a small increase in top speed requires a disproportionately huge engine.

### THE SECRET IS BUBBLES

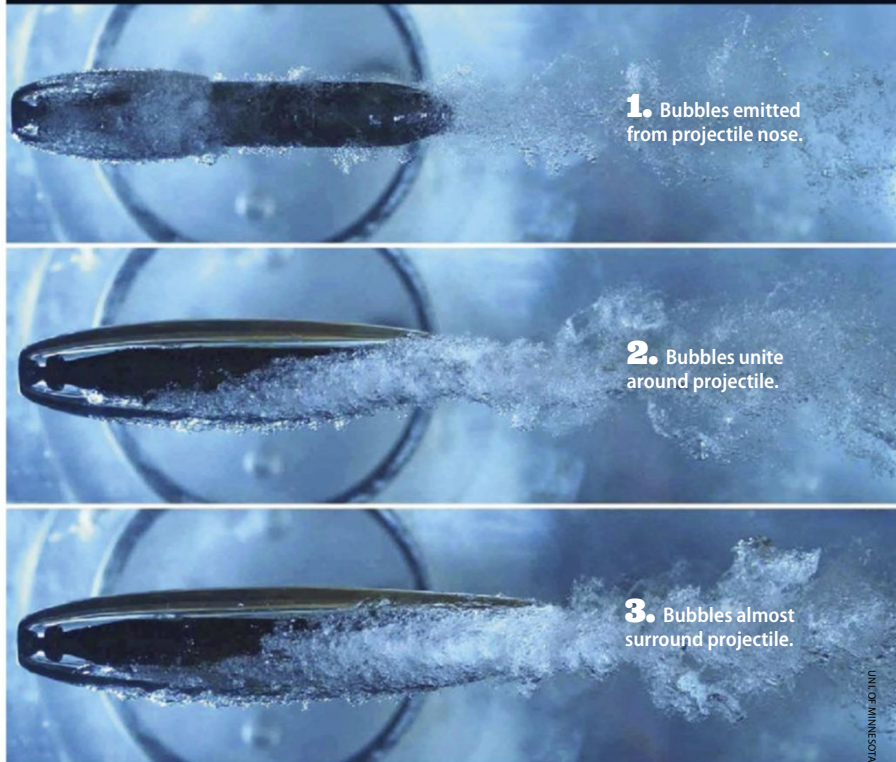
If the water drag is eliminated, the sub's top speed will suddenly be multiplied – and that is exactly what supercavitation is about. Supercavitation can be observed when a projectile is shot through water. At first, the projectile will drag an air bubble along from the surface. If the speed is sufficiently high, and the projectile is shaped in a particular way, it can continue through the water surrounded by the air bubble. The US Navy has already developed projectiles that take advantage of supercavitation, but unfortunately, the air bubble is dissolved after a few seconds, making the projectile lose speed very quickly.

If supercavitation is to continue its effect for a longer period of time – which is necessary in order for a submarine to take advantage of the principle – the air bubble must be supplied with compressed air or gas from the sub itself. That can be done at the nose of the hull via a nozzle equipped with small valves, from which gas flows in the shape of bubbles. The bubbles will soon unite and surround the entire vessel, making the submarine avoid direct contact with the surrounding water, and so remain unaffected by water drag.

### CHINESE BREAKTHROUGH

During the Cold War, the Soviet Union managed to develop a torpedo known as Shkval, which can keep up the effect of supercavitation for long periods of time by emitting gas bubbles from its nose and race through the water at speeds of 370 km/h. Since then, several countries have been working on developing subs that take advantage of the same principle. However, the scientific activities are veiled in secrecy, as the development of supercavitation submarines are military matters. But Russia, China, Iran, and the US are reportedly developing supercavitation submarines. Recently, Chinese engineers published several considerable scientific breakthroughs. Although they don't want other countries to catch up with them in the development of supercavitation subs, they have published a series of scientific articles, which disclose some information as to how some of the most significant challenges to obtaining supercavitation could be overcome.

## EXPERIMENT PROVES THE THEORY



Like the Chinese engineers, researchers from the US University of Minnesota and other places are developing a vessel that can take advantage of the supercavitation principle.

### DISSOLVENTS MAINTAIN THE BUBBLE

The Chinese scientists made use of a combination of calculations and simulations, borrowing many of the principles from another wave research discipline: sound research. Moreover, they shot projectiles through liquid to see, how the supercavitation bubble develops and perishes. One of the

challenges consists in producing a stable air bubble. Air bubbles in water are volatile and very difficult to control. Normally, bubbles forced out of the nose of a sub will soon lose their shape and size as a result of the pressure of the surrounding water, the frictional resistance against the hull, etc.

But the Chinese engineers discovered that water-soluble dissolvents, which we know from ordinary dishwashing liquid, can reduce the frictional resistance of the bubbles against the hull. By spraying dissolvents through the nozzle at the nose of the sub along with the bubbles, engineers can produce a membrane around the vessel. So, the bubbles maintain their shapes for a longer time.

### CHEMISTRY REPLACES RUDDER

Dissolvents have also proved to be the solution to other great challenges. At a speed of 5,000 km/h, a major challenge consists in controlling the submarine. Scientists cannot use a rudder or a guide fin to alter the course without affecting the speed and risking to destroy the air bubble ►

### Coveted method put US spy behind bars

In 2000, a former captain of the US Navy, Edmond Pope, was arrested by the Russian intelligence service. He is alleged to have snuck top secret information about the Russian Shkval supercavitation torpedo out of the country.





► surrounding the vessel. The Russian Shkval supercavitation torpedo features guide fins, but moves at a maximum speed of only 370 km/h – and even then it is a challenge to control the torpedo. However, the Chinese engineers have discovered that they can control the sub by dosing the amount of dissolvents sprayed onto the hull. By regulating the dissolvents, the scientists can produce very slight changes in frictional resistance, manoeuvring the sub without destroying the air pocket.

But the Chinese engineers still face a number of major challenges. In order for the supercavitation bubble to be produced, the submarine must achieve a speed through the water of 75-100 km/h in only 1-2 seconds. The Shkval torpedo is shot through a torpedo tube by means of hydraulic pressure, which can send the torpedo into the water at a speed of around 100 km/h,


after which the torpedo's rocket engine takes over. A supercavitation submarine would probably have to accelerate to 75-100 km/h by means of a solid fuel rocket engine based on for instance hydrogen or sulfur, which requires explosive combustion. The Shkval torpedo is equipped with a solid fuel rocket engine, but it only has a reach of 10-15 km. A rocket engine has not yet been developed that could make a supercavitation sub travel a longer distance.

So, the sub would probably need to be equipped with a two-stage engine, in which the first step is the rocket engine, that would very quickly accelerate the sub to 75-100 km/h. When supercavitation has been achieved, another engine with more adjustable combustion – a so-called throttleable engine – could take over, gradually accelerating the sub to its maximum speed.

## MANY CHALLENGES REMAIN

If the scientists manage to develop a supercavitation submarine, many challenges will still remain. For instance, they must make sure that the sub will not hit any obstacles en route. At speeds of 5,000+ km/h, it would be a disaster, if the sub ran into, for instance, a 190 tonne blue whale.

The route must also be planned so the sub avoids undersea reefs such as the Midatlantic Ridge. And no matter if the sub's route includes as few obstacles as possible, the vessel must have a navigation radius of several hundred km to be able to avoid obstacles. A safe passage would require the development of brand new types of sensors that could monitor the waters.

All these things must happen before our oceans fill with supersonic submarines. But who knows – one day they could be a reality. 

# RUSSIAN SUPERCAVITATION TORPEDO

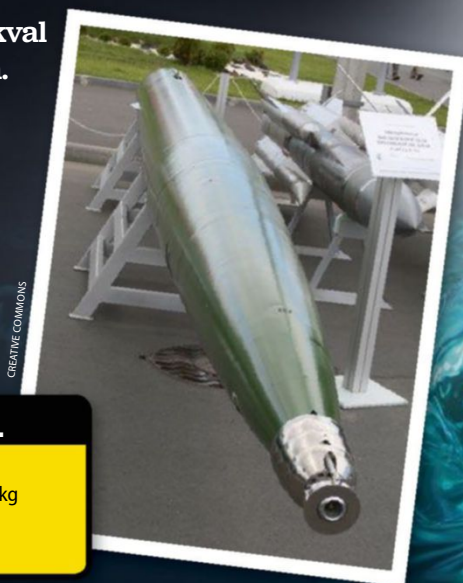
**Taking advantage of air bubbles and supercavitation, the Soviet Shkval torpedo is able to tear through the water at speeds of up to 370 km/h.**

The Russian VA-111 Shkval torpedo is an example of supercavitation used in practice. The development of the torpedo began in 1963 in Moscow, but the torpedo was not put into service until 1977. In the 1990s, the weapon was developed further and equipped with control systems. The Shkval boasts a top speed of over 370 km/h and has a range of 10-15 km. The torpedo immediately made the US military

initiate its own scientific programmes, but we know very little about the results.

In 2006, Iran claimed to have tested a torpedo with a top speed of 360 km/h, which was reportedly a revised Shkval version.

**The Shkval torpedo emits air bubbles from its nose, producing supercavitation.**



### VA-111 SHKVAL

**Total weight:** 2,700 kg  
**Warhead weight:** 210 kg  
**Length:** 8.2 m  
**Diameter:** 0.5 m

**5 GUIDE FINS** can be pushed out or pulled in, making the torpedo switch course.

**4 A ROCKET ENGINE** with solid fuel – probably based on lithium – allows the torpedo to obtain a speed of approximately 370 km/h.

**3 STORAGE TANKS** for gas, which is forced through nozzles at the nose in a compressed state.

**2 CONTROL ELECTRONICS** make sure that the torpedo hits its pre-programmed target.

**1 A CAVITATOR** at the nose forces gas out of small openings. The bubbles produce an air pocket, in which the torpedo moves.



# THE WILDEST SUBMARINE RECORDS



## 83km/h

is reportedly the highest speed obtained by a manned sub. It was achieved by the Russian K-162 Titanium submarine in March 1970. The record has not been confirmed.

CREATIVE COMMONS

## 1,676m

is the maximum depth of the Triton 5500/2, making it the plexiglass submarine that can dive the deepest.

TRITON SUBMARINES



## 60 DAYS

AND 21 HOURS was the time in which the US nuclear sub USS Triton completed the first submerged circumnavigation of the world in 1960. The Triton travelled 49,491 km at an average speed of 33 km/h.



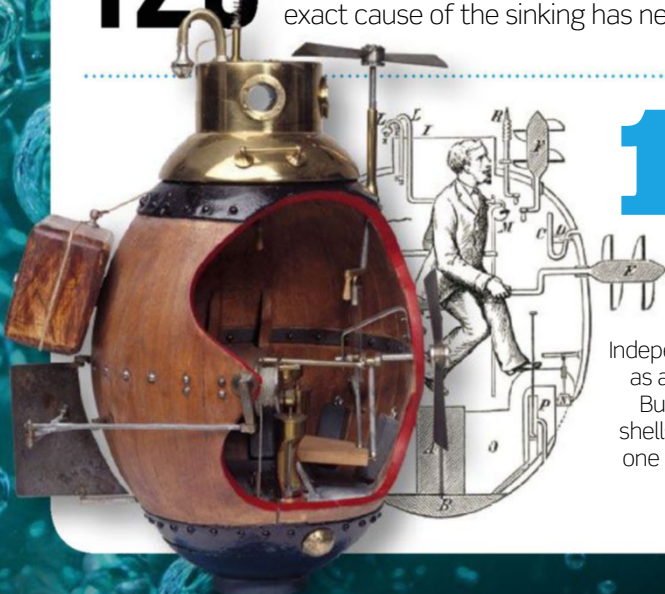
## 1954

was the year in which the first nuclear-powered sub, the USS Nautilus, was launched into the Thames River in the US. The Nautilus was the first sub that could remain submerged for long periods of time, producing its own oxygen and nuclear fuel.



## 129

died in the worst submarine accident ever, when the American USS Thresher sank during an exercise mission in the North Atlantic on 10 April 1963. The exact cause of the sinking has never been established.



## 1775

was the year in which the first sub for war purposes was launched in connection with the American War of Independence. It was named Turtle, as according to its inventor, David Bushnell, it looked like two turtle shells. The Turtle was designed for one person and powered by hand-cranked propellers.

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## 175m

is the length of the world's biggest sub, which is still regularly used. NATO describes the Russian Dmitry Donskoy as part of the Typhoon class. Typhoon subs are known to be among the most silent when fully submerged.



# And Baby makes

Soon, all women with hereditary diseases could nevertheless have healthy children. A new method removes disease-causing genes from the egg cell's mitochondria, replacing them with healthy genes from a donor. The child will be healthy, but gets genetic material from three parents. The UK has approved the new therapy, and other countries could follow...

By Lea Holtze

**F**or thousands of women all over the world, the dream of having a child also involves fear. The women carry genes that may cause incurable diseases such as muscular atrophy and heart and liver conditions in their children.

For decades, neurologist Doug Turnbull from Newcastle University in the UK has worked with patients who were born with severe diseases. Now, he has developed a new breakthrough method which makes sure that specific genetic diseases will no longer be passed on to children. The therapy uses an egg donor, and the result is a healthy child with three genetic parents – the birth mum and dad plus a female donor who contributes part of her egg cell. The House of Commons in the UK recently

approved the treatment, but individual clinics must apply for permits.

## MITOCHONDRIA CONTAIN GENES

About 99.9 % of our genetic material is located on the chromosomes in our cell nuclei, but the remaining 0.1 % sits in the mitochondria, known as the "power stations" of cells, because they convert oxygen into energy. In women who can benefit from the new treatment, the disease-causing DNA is located in this specific place. The mitochondria are found in the cell plasma surrounding the cell nucleus and are always inherited from the mother. To avoid passing the defective mitochondria on to the child, scientists take

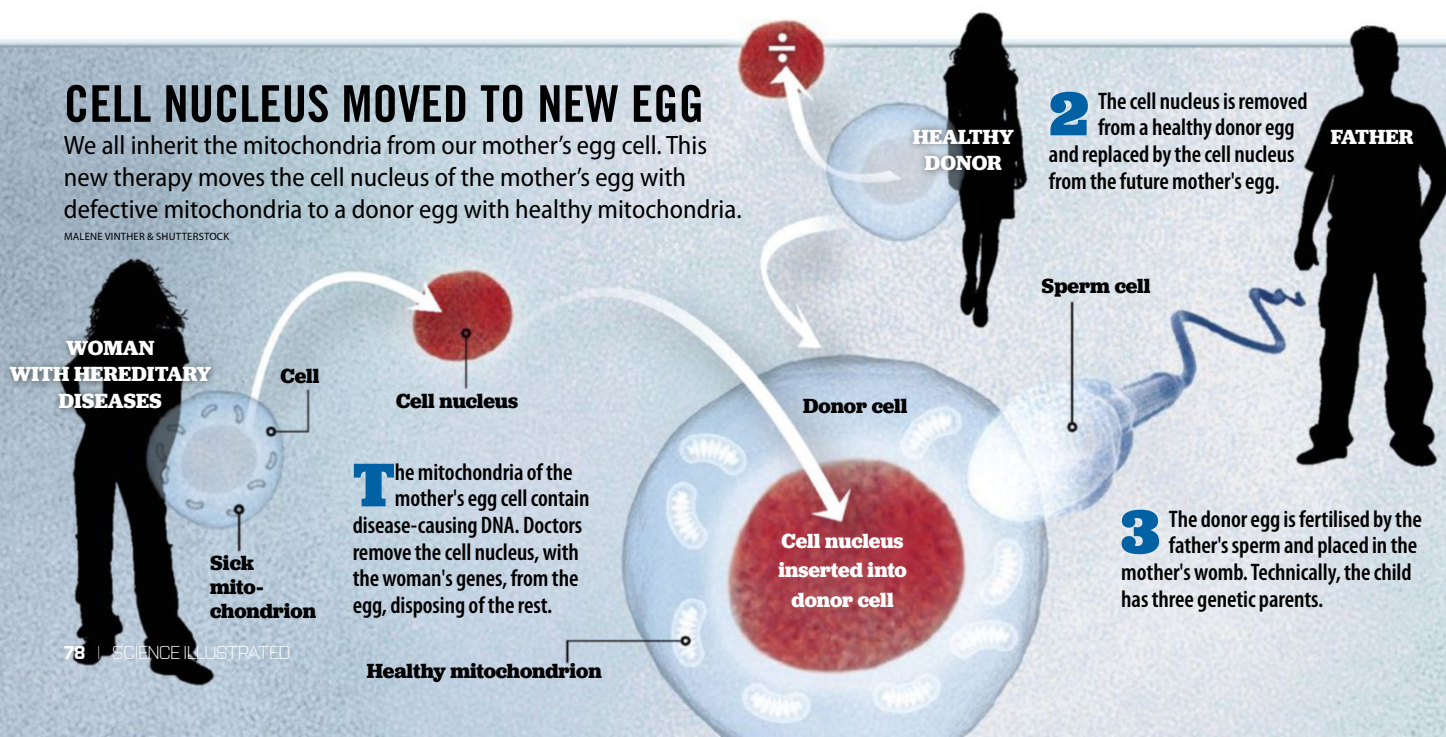
a donor egg from a woman with healthy mitochondria. The nucleus with the donor's genes is removed, leaving the mitochondria, and replaced by the nucleus of the mother's egg. Subsequently, the egg is fertilised with the father's sperm and implanted in the mother's womb. The result is a healthy baby with 99.9% genetic information from its parents and 0.1% from the egg donor.

The mitochondria are critical to body function. If the mitochondria do not work, brain, heart, and muscles are particularly badly affected, as they need the most energy. So, scientists compare the new method to replacing a defective car engine. But according to critics, it is not all that simple, and the therapy is still subject to debate in the UK. Some opponents are

## CELL NUCLEUS MOVED TO NEW EGG

We all inherit the mitochondria from our mother's egg cell. This new therapy moves the cell nucleus of the mother's egg with defective mitochondria to a donor egg with healthy mitochondria.


MALENE VINSTER & SHUTTERSTOCK





# ...four?

against the principle of altering genes, which are passed on to future generations and could have a long-term effect. Other critics refer to recent scientific research showing that the mitochondria influence ageing and the risk of developing cancer, autoimmune diseases, and more.

However, several independent scientists consider the therapy harmless. The mitochondria are not artificial, they come from a human donor and only contain 37 genes. The real parents still contribute all the approximately 23,000 genes of the cell nucleus, which determine the child's personal characteristics such as hair and eye colour, height, weight, and temperament. 

When the cell nucleus has been substituted, the egg is fertilised with the father's sperm.

SHUTTERSTOCK

## AVOIDABLE INHERITED AILMENTS:

■ MUSCULAR ATROPHY

■ HEART DISEASES

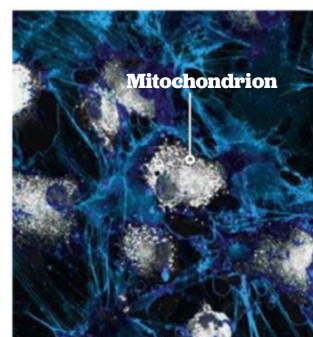
■ LIVER DISEASES

■ BRAIN DISEASES

■ POOR SIGHT/BLINDNESS

### Mitochondria Provide Energy For Cells

Our cells are full of mitochondria in the plasma surrounding the nucleus. The number varies greatly, and cells that consume lots of energy may contain thousands of the tiny power stations with diameters of only one micrometre. If the energy demand grows, such as in a muscle cell, the mitochondria can divide. The cell power stations contain 37 genes - or just 0.1 % of our total genetic material.



Cells with a great energy demand contain thousands of microscopic power stations.



# TRIVIA

PUT YOUR KNOWLEDGE  
TO THE TEST

1. Which scientific instrument takes distinctive grey images of very very tiny objects?

2. Ceres, the dwarf planet currently being orbited by the Dawn spacecraft, is named after the Roman goddess of what?

3. A Japanese sewage treatment plant found higher yields of which precious metal than some of the world's top mines?

4. At its final moment of approach before landing, what level of engine thrust did the Space Shuttle pilots use?

5. How many teeth does a healthy sheep have in the top of its mouth?

6. In 1978, Emilio Marcos Palma was the first person to be born on the mainland of which continent?

q. 1

7. In English and some of the other European languages, "wheat" is indirectly named after which colour?

8. The distance from the tip of the middle finger to the elbow is an ancient measurement that historical figures such as Noah called what?

9. Digital computers use "bits" to manipulate data. What do quantum computers use?

10. When you multiply a number by itself, and then by itself again, what are you doing?

ANSWERS ON p82!

## Trivia Countdown (use fewer clues, get a higher score!)

	5 POINTS	4 POINTS	3 POINTS	2 POINTS	1 POINT
<b>1. TECHNOLOGY</b> <b>Name this space mission</b>	The mission was launched towards the Moon on 11 April 1970 and landed in the Pacific five days later.	The commander was Jim Lovell of the US, and the crew was made up of three people.	Originally, the crew was supposed to land on the Moon, but that did not happen.	An explosion in one of the spacecraft's oxygen tanks made it impossible for the crew to complete its mission.	Tom Hanks stars as Jim Lovell in a film from 1995 with the same name as the mission.
<b>2. ASTRONOMY</b> <b>Name this constellation</b>	Rigel is the seventh brightest star in the sky and the brightest star of this constellation.	Consisting of seven bright stars, the constellation is visible in the northern hemisphere in November-February.	Located on the equator of the sky, it can be observed from both the northern and the southern hemispheres.	The constellation is also known as the hunter of the sky, which often fights another constellation: Taurus.	Three bright stars in a row make up a belt, while four stars surrounding the three are his shoulders and feet.
<b>3. ZOOLOGY</b> <b>Name this animal</b>	This mammal is the biggest modern predator, possibly the biggest ever predator with teeth.	This big whale primarily feeds on different types of squid, which it catches at depths below 2000 m.	It only has teeth in the narrow lower part of its mouth. In the upper part, there are holes to match the teeth.	It is named not for its shape, but because of a thick white liquid that can be extracted from its head.	In 1851, Herman Melville immortalised a huge white whale of this type in his novel Moby Dick.



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## TWO-SPINED SPIDER

**Scientific Name:** *Poecilopachys australasia*

**Distribution:** Eastern Australia, often found on the underside of citrus leaves. Has been introduced to New Zealand.

**Status:** Female well known, but male poorly studied and once thought to be a different species.



PHOTOGRAPHY BY DAMON WILDER

# PRETTY LITTLE KILLERS

Spore a thought for this two-spined spider, whose ancestors spent perhaps a million years or more evolving this distinctive abdomen which both allows the spider to blend-in among foliage and flowers, but also present an unpalatable spiky look to curious birds and other predators. To us though, in this picture, it looks like a rather tasty little snack-sized Pavlova. Complete with berry sauce and two artful tufts of lightly toasted meringue on top.

The Two-spined spider is a member of the Araneidae family of spiders, known to most people as orb-weavers. These are the spiders who create the distinctive circular webs that look so beautiful on a dewy morning.

Despite the relatively tiny size of these predators, it is amazing how much

intelligence an orb-weaver will show. These spiders love our pergolas and verandas and the anchor points they provide, and it's an essential part of an Australian summer to step outside on a balmy evening and get a face-full of web. Yet, after just two or three nights of screaming and crashing through a spider's web, on the next night she'll build it slightly to the left or right of where you keep walking. Mere instinct? Perhaps - but it definitely shows the spider has at least some kind of memory.

Like all orb-weavers, it's this female *Poecilopachys* who builds the web. The male is so tiny, shy and retiring that for some years, entomologists thought he was a different species altogether!

You can find this spider in citrus trees, where the underside of the leaves provide shelter and shade during the day.



## THREE-SIDED HUNTER


The Arkys or "triangle" spiders have a distinctive triangular abdomen. Unlike the two-spined spider, they don't weave webs but rather lie in wait and ambush their prey. The abdomen helps the spider blend in to vegetation, or at least present a shape that doesn't look like a predator.

### TRIANGLE SPIDER

**Scientific name:** *Arkys lancearius*

**Distribution:** Throughout eastern Australia

**Status:** Common and easy to find.

If you have the time, sit and watch her build her web in the early evening - it's a fascinating mix of engineering, abseiling and extreme base jumping! 

**TRIVIA ANSWERS** 1. Scanning electron microscope. 2. Agriculture. 3. Gold. 4. 0%. The Shuttle glided the whole way down. 5. None. 6. Antarctica. 7. White. 8. The cubit. 9. Qubits (quantum bits). 10. Cubing it. **Trivia Countdown:** Name this space mission: Apollo 13 Name this constellation: Orion Name this animal: Sperm whale



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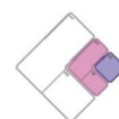
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